RI 9577

REPORT OF INVESTIGATIONS/1995

Investigation of Acid Production, Leaching, and Transport of Dissolved Metals at an Abandoned Sulfide Tailings Impoundment: Monitoring and Physical Properties

UNITED STATES DEPARTMENT OF THE INTERIOR

UNITED STATES BUREAU OF MINES

U.S. Department of the Interior
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Cover: An abandoned sulfide tailings impoundment discharging acid drainage and dissolved heavy metals.

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm	centimeter	mL/min	milliliter per minute
cm/s	centimeter per second	mm	millimeter
g/cm^3	gram per cubic centimeter	mV	millivolt
h	hour	pct	percent
ha	hectare	ppb	part per billion
kg	kilogram	ppm	part per million
m	meter	s	second
m^3	cubic meter	vol pct	volume percent
m/d	meter per day	μL	microliter
mg/L	milligram per liter	μm	micrometer
m/m	meter per meter	μS/cm	microsiemens per centimeter
min	minute	°C	degree Celsius
mL	milliliter		

INVESTIGATION OF ACID PRODUCTION, LEACHING, AND TRANSPORT OF DISSOLVED METALS AT AN ABANDONED SULFIDE TAILINGS IMPOUNDMENT: MONITORING AND PHYSICAL PROPERTIES

By B. M. Stewart,[1] B. C. Williams,[2] and R. H. Lambeth[1]

ABSTRACT

Researchers at the U.S. Bureau of Mines conducted a long-term groundwater monitoring and site characterization program at an abandoned 10-ha, acid-producing, copper-gold tailings impoundment in north-central Washington State. The purpose was to investigate contaminant release and transport, and attenuation mechanisms in the tailings, sediments below the tailings, and gravels downgradient of the impoundment. This report summarizes the monitoring results and physical properties of the tailings, the sediments below the tailings, and the groundwater system associated with the tailings.

Water samples from the vadose and saturated zones of the impoundment were analyzed for 15 constituents. Concentrations of the same constituents were determined in water samples up to 3 m beneath the impoundment and in the shallow colluvium and deep bedrock at 76, 335, and 550 m downgradient and 168 m upgradient.

Constituent concentrations within the tailings are quite variable and are influenced by pH, depth of oxidation, grain-size differential (surface area), hydraulic gradient, groundwater mixing, and the presence of hardpan layers, carbonaceous material, and organic matter. Most of the metal constituents decreased to background or near-background concentrations in the farthest downgradient well.

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INTRODUCTION

Cleanup of inactive mining-related sites and protection of the environment during current mining is a significant issue in the United States. The control of water pollution from mining and milling wastes is addressed under the Clean Water Act, which regulates the discharge of pollutants into surface waters; the Resource Conservation and Recovery Act (RCRA), which classifies the hazard potential of wastes; and the Comprehensive Environmental Response Compensation and Liabilities Act (CERCLA), which was written to guarantee the cleanup of sites not covered by other laws.

It has now been recognized that many inactive or abandoned mine sites are sources of contaminated water. Some of these mines have been placed on the National Priorities List under CERCLA and the Superfund Amendment and Reauthorization Act.

In 1988, the U.S. Environmental Protection Agency (EPA) significantly revised guidance documents and activities and prepared a National Contingency Plan that encourages and supports the use of innovative treatment technologies at Superfund sites. One provision of the plan includes selecting permanent, long-term remedies, with the highest priority for treatment to be given to "liquids, other highly mobile materials, and highly concentrated toxic compounds" (EPA, 1988).

There are currently very few, if any, cost-effective technologies to clean up surface and/or ground waters that have been contaminated by mining and milling wastes at inactive sites. Because of the complexity of the chemical and physical factors that contribute to water contamination from mining wastes, researchers at the U.S. Bureau of Mines (USBM) are conducting long-term studies on the generation, mobilization, and fate of heavy metals and other contaminants in these wastes. The results will be used to aid in the development of remediation strategies and to identify additional data needed for remediation.

The generation of acid and subsequent metal dissolution in tailings impoundments is a complex biogeochemical process involving the oxidation of pyrite and other sulfides and includes several inorganic reactions that depend upon such factors as pH, oxidation-reduction potential (Eh), oxygen availability, and the availability of other oxidants, such as ferric iron (Fe^{3+}). Although oxygen initiates sulfide oxidation, at low pH levels, the important rate-determining step(s) may involve other oxidants, such as ferric iron instead of oxygen (Nordstrom, 1982). Sulfide oxidation may also be directly or indirectly catalyzed by the presence of bacteria of the *Thiobacillus* genus and by other species of sulfur- and/or iron-oxidizing bacteria. Sulfides that are oxidized by oxygen and other oxidants are the source of sulfates and H^+ (acid) in solution. The acid dissolves and is neutralized by carbonates, aluminosilicates, and existing oxides, and by secondary aluminum hydroxides (Dubrovsky and others, 1985). Sulfates and hydroxide minerals form as precipitates when they reach geochemical saturation, depending upon the reaction kinetics. These reactions may occur near the sulfide source as well as downgradient from the point of sulfide oxidation. The degree of moisture saturation can influence the primary oxidation mechanism. A study by Taylor and others (1984) indicates that oxidation of sulfides in anaerobic, water-saturated environments occurs primarily by chemical oxidation pathways, whereas oxidation of sulfides in well-aerated vadose zone environments occurs mainly by microbially mediated pathways.

This Report of Investigations (RI) describes a research conducted at a specific mine waste site. It includes site characterization and results of analyses of water quality data collected in the vadose zone, the saturated zone, the sediments below the waste, the shallow unconsolidated aquifer, and deep zones of weathered bedrock at various distances downgradient from the waste. The primary objectives of this investigation were (1) to determine the physical property characteristics of the tailings and associated formations that affect acid production, leaching, and transport of dissolved metals from the waste and (2) to report existing water quality and other site-specific geological, physical, and hydrologic data that may be used for future site remediation work.

SITE DESCRIPTION AND SELECTION

SITE CRITERIA

The research objectives led to selection criteria for a tailings impoundment. Ease of access to the impoundment and adjacent watersheds were primary considerations. The following were also important:

1. A phreatic surface within the tailings profile, preferably in hydraulic connection with a shallow aquifer. This criterion permits the vadose zone to be compared with the saturated zone. If the tailings were not separated from the underlying material with a liner, the direct contact would permit analysis of free drainage, as well as upwelling, depending upon hydraulic conditions.

2. A vadose zone no less than 2 m thick to ensure that there was an adequate thickness to identify changes in characteristics such as oxygen content.

3. A significant amount of sulfides and few carbonates, to ensure that the tailings were acid producing. Such a condition is representative of most sulfide mine wastes.

4. Tailings and water slurry yielding acidic pH values, which would also support the belief that the tailings were acid producing.

5. An impoundment where there had been relatively little disturbance since the original deposition of the tailings. Postdepositional reworking of tailings might destroy or confound earlier distributions of certain physical or chemical properties with respect to depth. Because the kinetics of some oxidation reactions are slow, physical and chemical characterizations should most closely approximate "equilibrium" (given age, location, and climate) if the tailings were undisturbed.

SITE DESCRIPTION

After visits to many different sites, the site chosen for this research was an abandoned gold and copper tailings impoundment on the eastern slope of the Cascade Mountains in Washington State. The site receives an average of 370 mm of precipitation per year. Temperatures range from -36 to 41 °C, and the annual average is 7 °C. Figure 1 is a low-angle photograph of the research site looking down the valley to the southeast. The impoundment measures approximately 200 by 46 m, with an average depth of 6.1 m and a surface elevation of about 567 m above sea level. It contains about 33,100 m^3 of material. The phreatic surface, which varies spatially and temporally, is approximately 3 to 5 m below the ground surface. A cross section of the impoundment is shown in figure 2.

The valley in which the impoundment is located is a surface expression of a northwest-trending, near-vertical, tension-gash fault in midacidic metavolcanic bedrock. The valley floor is covered with a veneer of remnant gravel, and numerous calcareous and carbonaceous lake beds, some now dry, dot the floor. The tailings were deposited on top of one of these lake beds and next to a small pond. The upper meter of the silty lake sediments below the tailings is particularly rich in organic material, but the lateral extent of these sediments is not known. The geology of the valley in which the tailings impoundment was constructed is discussed in more detail by Lambeth (1992).

Mill records indicate that copper and zinc minerals were recovered by a conventional dual-circuit flotation system maintained at pH 10 or higher by the addition of lime. The mill was operating and depositing tailings into the impoundment between 1939 and 1953. The mined ore body, which is several miles away, is a chalcopyrite-sphalerite deposit containing gold and may be volcanogenic or (contact) metamorphic in origin. Mineralogical optical analysis of tailings from the chosen site indicated that tailings composition is 95 pct gangue minerals (primarily quartz and plagioclase) and 5 pct sulfide minerals (e.g., pyrite, chalcopyrite, sphalerite, and trace amounts of galena). No carbonates from the tailings were observed. Slurries composed of surface tailings mixed with deionized water yielded pH values in the range of 4 to 5. With the exception of one 2-m-deep pit (presumably dug in recent years to determine whether it would be economical to remill the tailings), these tailings have remained undisturbed since they were deposited.

The gravel aquifer under the tailings is recharged from bedrock sources and local precipitation. The flow direction is from the topographic high at the northwest end of the site toward the topographic low at the southeast end. On the basis of upward vertical gradients between the fractured bedrock and gravel aquifer at the locations of wells BKG, M2, and M5 (figure 3), the base flow in the gravel appears to be locally augmented at certain times of the year by upward groundwater discharge from the fractured bedrock. This groundwater probably discharges into the gravel and flows under, around, and possibly into the tailings and the underlying silt. However, at well M4 and in the fall at well M2, the vertical gradient is downward, indicating possible leakage from gravel to bedrock. Precipitation infiltrates the tailings impoundment and may possibly flow through the underlying deposits of calcareous and carbonaceous silt and enters the gravel aquifer. As contaminated tailings pore water leaves the tailings, a series of processes occur that influence contaminant concentrations downgradient. These include hydrogeochemical changes, dilution, dispersion, and advection.

There may be some tendency for infiltrating water to move horizontally when it encounters abrupt zones of relatively lower hydraulic conductivity. This horizontal flow may occur along layered heterogeneities in the tailings, such as hardpan, and also at the contact between the tailings and underlying organic matter and silts. If substantial horizontal flow does occur at the base of the tailings, pore water may eventually enter the colluvium at the edges of the impoundment, where the lake sediments stop. These sediments may actually have been removed in the vicinity of the downgradient end of the impoundment when the dam was constructed; if so, downward drainage into the colluvium would be enhanced just upgradient of the dam. Evapotranspiration may account for some portion of the water lost from the tailings impoundment.

MONITORING WELL DRILLING AND INSTALLATION

Forty-five polyvinyl chloride (PVC) and BAT Envitech, Inc., groundwater samplers for monitoring wells were installed at the field test site and are described in table 1. A plan view of the research site and the monitoring well locations is shown in figure 3. The well completion reports are given in appendix A.

Table 1.—Description of wells

No. of wells	Type	Description	Location
11	PVC	P wells	Saturated zone of tailings, colluvium, and sediments below tailings.
14	BAT	B wells	Vadose and saturated zone of tailings.
3	PVC	BKG wells: multiple completions in one hole.	Upgradient colluvium and bedrock.
17	PVC	M wells: multiple completions in five holes.	Downgradient colluvium and bedrock.

P WELLS IN AND BELOW TAILINGS

The P wells in and below the tailings were installed using the hollow-stem auger method. With this method, holes are drilled to the desired depth with augers having an outside diameter of 20.3 cm and an inside diameter of 8.573 cm. The PVC casing is lowered down the inside hollow portion of the augers and the augers are retrieved, leaving the casing in place.

The P wells themselves consist of schedule 40 PVC pipe with an inside diameter of 3.18 cm and 61-cm-long bottom sections perforated with 0.05-cm slots. As much as possible, all wells installed after 1987 in the saturated zone of the tailings or below the tailings were installed according to the Minimum Standards for Construction and Maintenance of Wells established by the Washington State Department of Ecology (WSDOE, 1988). Because of the granular nature of the tailings, filter packs were not used, and the saturated tailings were allowed to cave around and above the perforated section (natural completion). A bentonite plug was installed from the caved-in portion to about 130 cm below the surface. A 122-cm-long protective cover with a locking cap was placed over the PVC pipe and grouted in place. Once in place, the wells were allowed to stabilize for 1 week and then developed. Development consisted of surging and pumping until the water was relatively clear. After development, dedicated 0.95-cm tubing was installed in each well for sampling.

To determine contaminant concentrations below the tailings, wells P3A, P3B, and P3C (figure 3) were drilled to 6.4 m (about 30 cm below the tailings), 5.8 m (base of the tailings), and 7 m (about 90 cm below the tailings), respectively. The 61-cm perforated section of well P3A was placed at the interface between the tailings and the organic-rich layer at the top of the lake sediment, with the upper half of the perforated section in the tailings and the lower half in the organic-rich layer. The perforated section of well P3B was completed in the tailings base, and the perforated section of well P3C was completed in the silt below the organic-rich layer. Well P3 was completed at 9.1 m, approximately 3 m in the silt below the tailings and below the organic-rich layer and just above the underlying gravel.

The depths of the P wells are shown in table 2 and are measured from ground level to the bottom of the 61-cm-long perforated section. Also shown in table 2 are the completion media and the sampling method for each well. Well P7 (figure 3) never contained water and therefore is not considered in this RI.

B WELLS IN TAILINGS

Also shown in table 2 are the depths, completion media, and sampling method for the B wells. Installation of the BAT samplers was done according to Petsonk (1985). The BAT sampler was chosen as the water and pressure sampling apparatus for the vadose zone and some locations in the saturated zone. This instrument operates in a manner similar to a suction lysimeter or tensiometer. It consists of a tip with a cylindrical porous filter. The porous filter chamber is topped by a septum, and the unit is installed downhole at the end of an access tube. Water sampling vials or a pressure transducer are fitted with a hypodermic needle connection. When the sample housing or transducer is lowered downhole, a spring-loaded apparatus pierces the septum to establish hydraulic connection with the tailings material. A cross section of the BAT sampler is shown in figure 4.

The BAT sampler was used in this study because it prevents exposure to air during the lengthy sampling process. At one sampling location in the vadose zone, it took at least 12 h to yield a 40-mL sample. Exposure to air for 12 h would have risked the possibility that great changes could take place in iron chemistry.

To sample liquids in the vadose zone, BAT samplers with ceramic tips having a pore size of 1 to 2 μm were installed. The small pore size of the ceramic permits liquid samples to be withdrawn from the vadose zone according to the principles of capillarity because the pore size is comparable to that of the fine-grained tailings. Prior to installation, the ceramic tips were boiled in deionized water to force all gas from the pore spaces. They were then transported to the site in a bucket of water so they would remain saturated. The ceramic tips were pushed (with a mobile drill rig) to the desired depth immediately after being removed from the bucket in order to establish good hydraulic contact with the fine-grained tailings. Subsequent water samples have not shown any large particles, which indicates that the installations were successful, that is, that none of the ceramic filters have cracked. After 1 week, considered sufficient time for hydraulic contact to develop between tip and tailings, multiple-tip volumes were drawn through the tips to flush out deionized water with tailings pore water. One disadvantage of the BAT samplers was that at 61 cm, the tips became desaturated a few months after installation, and water samples could not be obtained. Consequently, wells B1-2c and B2-2c were not used. Gas samples, however, were obtained from wells B1-2p and B2-2p.

Table 2.—Monitoring wells in and below tailings[1]

Well ID[2]	Depth, m	Completion media
P1	4.9	Organic/gravel (BT).[3]
P2	5.7	Gravel (BT).
P2A	4.9	Saturated tailings.
P3	8.9	Saturated volcanic ash (BT).
P3A	6.5	Organic layer (BT).
P3B	5.9	Saturated tailings base.
P3C	7.1	Saturated ash/organic (BT).
P4	4.6	Saturated tailings.
P5	4.4	Fluctuation zone.[4]
P6	5.0	Saturated tailings.
B1-2	0.6	Vadose tailings.
B1-4	1.2	Vadose tailings.
B1-7	2.1	Capillary zone.
B1-16	4.9	Saturated tailings.
B2-2	0.6	Vadose tailings.
B2-4	1.2	Vadose tailings.
B2-8	2.4	Vadose tailings.
B2-16	4.9	Saturated tailings.

[1]Wells P1 through P6 were sampled with a vacuum pump; wells B1-2 through B2-16 were sampled with the BAT sampler.

[2]The first part of the label is the sample location, and the second part following the hyphen is the sample depth in feet from ground level.

[3]BT indicates the completion media are at the base of the tailings or below the tailings.

[4]The fluctuation zone refers to that zone through or within which the water table fluctuates from its highest point to its lowest point in any given year.

Thermoplastic tips with larger pore sizes were installed to collect water samples from the saturated zone. A small pore size is not required if water is being sampled at positive pressure. The thermoplastic tips did not require saturation prior to installation because they were installed below the water table, and their large pore size permitted water to displace air freely when suction was applied.

BKG AND M WELLS UPGRADIENT AND DOWNGRADIENT OF TAILINGS

Monitoring wells were installed upgradient of the tailings to determine water quality before the water had been influenced by the tailings and downgradient of the tailings to determine water quality after the water had been influenced by the tailings. The five downgradient wells (M wells) were drilled on pads leveled by a bulldozer. The pads were constructed perpendicular to and across the downgradient surface drainage. All the M wells were multiple completions with PVC casing at two or three different depths in each well. The shallow M wells (M1 through M4) were drilled using the downhole air-hammer method, and the deep M well (M5) and upgradient well (BKG) were drilled using the air rotary method. In both methods, temporary casing was installed through the gravels. Forced air was used to remove the cuttings.

After reaching the desired depth, the holes were flushed with air until the discharged water became relatively clear. Once this initial development was completed, the first monitoring well (schedule 40 PVC pipe with a 61-cm perforated section) was set, and a filter pack of 20/30 silica sand was placed around and above the perforated section. Next, a bentonite plug was placed above the filter pack by slowing pouring bentonite chips in the annulus between the casing and the PVC pipe. This procedure was repeated for the second and third wells in the multiple completion. The temporary casing was pulled after the monitoring wells were set in place. After the drill was moved off the hole, a 1.2-m-long protective cover with a locking cap was placed over the wells and grouted in place with a gravel-cement mix. At the surface, the mix was sloped away from the protective cover.

Wells M1 and M2 were placed on one pad 15 m apart and 76 m downgradient of the tailings impoundment. Wells M3 and M4 were placed on a second pad 18 m apart and 335 m downgradient, and well M5 was placed on a third pad 550 m downgradient. The BKG well was located about 175 m upgradient of the tailings pile and about 30 m upgradient of the standing water pond (figure 3). The depths from ground level to the bottom of the PVC casing for each completion in the upgradient and downgradient wells are shown in table 3. Also shown in table 3 are the media (gravel or bedrock) in which the perforated section of the casing was located and the method of obtaining water samples. Well M3-5 never contained water and, therefore, was not used.

Table 3.—Background and downgradient monitoring wells[1]

Well ID	Depth, m	Completion media
M1-2	2.1	Colluvial gravel.
M1-3	3.4	Bedrock.
M1-8	8.5	Bedrock.
M2-4	4.0	Colluvial gravel.
M2-6	6.1	Bedrock.
M2-12	12.5	Bedrock.
M3-5	4.9	Colluvial gravel.
M3-10	9.8	Bedrock.
M4-5	5.2	Colluvial gravel.
M4-7	7.3	Bedrock,
M4-10	9.8	Bedrock.
M5-4	4.0	Colluvial gravel.
M5-23	22.9	Bedrock.
M5-53	53.4	Bedrock.
BKG-6	6.4	Colluvial gravel.
BKG-20	20.1	Bedrock.
BKG-43	43.3	Bedrock.

[1]All wells were sampled using the peristaltic method, except wells M5-53, BKG-20, and BKG-43, which were sampled with bladder pumps.

FIELD SAMPLING AND DATA COLLECTION

SOLID SAMPLES

During well construction in the tailings, disturbed samples were obtained using a split-barrel sampler. The sampler was driven with a 63.6-kg hammer and consisted of two standard 38-cm-long split tubes with 20-cm-long spacers at the top and the middle and a 9-cm-long shoe. It was possible to obtain a total of 116 cm (not counting the shoe space) of sample per drive. Continuous samples from the surface to the desired depth were collected from most holes. Below the water table, a rivet-type basket retainer was placed in the shoe of the sampler to aid in sample removal. Samples were obtained in 1987 and again in 1990 while installing additional monitoring wells (P3A, P3B, and P3C). The samples were used for detailed mineralogical analyses; determinations of grain size, specific gravity, clay content, and moisture content; sequential analyses of base-metal loading; and development of a detailed site cross section.

WATER SAMPLES FROM BAT SAMPLERS

Before the field sampling trips, BAT sampling vials were flushed and then evacuated with an inert gas (helium), thereby washing out all atmospheric gases, such as oxygen and carbon dioxide. The vacuum evacuation system was one designed and constructed by USBM staff. After several evacuation cycles were completed, the vials were removed from needle connections while in a vacuum, the magnitude of which was indicated by an in-line pressure valve. Any remaining molecules of gas in the vials were helium, so the sampling vessel was completely free of oxygen or carbon dioxide molecules. The system was designed with multiple ports so that six vials could be evacuated at once.

Collecting samples using the BAT system (figure 4A) yielded an independent airtight vial for each sample. One "purge volume" of liquid was always withdrawn prior to sampling and the contents discarded; this amount was a minimum of 10 mL, which constituted the "dead volume" inside the sampler, i.e., the volume that had resided in the vial since the previous sampling trip. Obtaining 40 mL of sample from the vadose zone using ceramic tips required 2 to 12 h. Thermoplastic tips, which have larger pores than the ceramic tips, yielded over 60 mL in 15 min from the saturated zone.

Liquid sampling vials were stored on ice for no more than 12 h before they were opened to analyze for Eh (using a platinum electrode) and pH (using a glass electrode). Electrical conductivity was not measured because none of the available probes could measure conductivities as high as those found in the pore waters. Bicarbonate titrations were not performed because all tailings pH values were already below the titration endpoint pH. Dissolved oxygen (DO) was not measured because the BAT sampling procedure exerts a strong negative pressure on water during sampling and has the potential to withdraw dissolved gases from solution. The omission of DO for these locations in the database is considered defensible because measured Eh was used as input to the computer code WATEQ4F. Sensitivity studies using this code indicated that the influence of DO on Eh status is insignificant in waters with low pH and large concentrations of dissolved iron.

After the Eh and pH measurements, the sample was immediately acidified with nitric acid for element analyses by an inductively coupled plasma emission spectra analyzer (ICP) in the laboratory. When time allowed, duplicate samples were collected for sulfate and chloride analyses using an ion chromatograph (IC). Separate aliquots from one sample run were preserved to a pH of 2 with hydrochloric acid for arsenic speciation analyses. Separate aliquots from two sampling trips were collected for laboratory iron speciation analyses.

Water samples taken with the BAT sampler were not filtered to 0.45 μm for several reasons. First, for the purpose of evaluating trends, the filtration capability of the ceramic tips (estimated by the manufacturer to be 1 to 2 μm) would be adequate. Second, the in-line filtration apparatus has several points where atmospheric air is trapped prior to sampling. A priority of the experimental design was to prevent exposure to the atmosphere during sampling; therefore, it was concluded that one order of magnitude of filter size (the difference between 0.45 and 2 μm) could be sacrificed to prevent compromising Eh, pH, and other parameters critical to sulfide oxidation. To verify this assumption, one complete sample run was filtered to 0.45 μm after being collected with a syringe-and-filter system (acquired after 1 year of sampling) to evaluate how the water quality data would compare with the data for the unfiltered (1 to 2 μm, effective) samples. In no case did an element concentration differ by more than 9 pct, and in most cases, differences ranged from 0 to 4 pct.

GAS SAMPLES FROM BAT SAMPLERS

Thermoplastic BAT sampler tips (which have larger pore sizes than the ceramic tips) were installed in the vadose zone to sample pore gas. The vials were flushed with helium and evacuated as described above. Only in rare instances, such as spring infiltration or installation into the capillary fringe, did these installations yield any liquid. The rest of the time, because these tips were installed dry, the pore entry pressure was so high that only gas could be sampled. The vials were maintained at cool temperatures until analyzed with a gas chromatograph.

WATER SAMPLES FROM PVC MONITORING WELLS

Water samples from all PVC monitoring wells were collected in two ways. A peristaltic vacuum pump connected to dedicated 0.96-cm tubing was used for the shallow wells and dedicated downhole bladder pumps were used for the deep wells. Prior to sampling, the water levels were measured and the wells purged. The purge amount was generally at least two tubing volumes. However, because of the long recharge time (up to 12 h) required for the tailings monitoring wells, only one tubing volume was purged for these wells. Duplicate 125-mL samples, one acidified with nitric acid to a pH of 1.5 and the other not acidified, were collected from each well. Prior to collection, the samples were filtered through a prefilter, a 0.8-μm filter, and a 0.45-μm filter, all separated by mesh spacers. The sample containers were filled to the top and immediately capped for minimum exposure to oxygen.

FIELD DATA COLLECTION

Water Properties

On-site water measurements included pH, DO, conductivity, Eh, and temperature. Calomel electrodes and platinum-type electrodes with silver-silver chloride reference cells were used to measure pH and Eh. A Clarke-type oxygen electrode and a flowthrough conductivity cell were used to measure DO and conductivity, respectively. When feasible, the electrodes, conductivity cell, and temperature probe were placed in a flowthrough chamber, and measurements were made as sample water passed through the chamber. When there was an insufficient amount of a sample to pass through the chamber, measurements were made in a small beaker. In some samples, alkalinity was measured using a field digital titration procedure.

Tailings Temperature

Tailings temperature data were collected for possible identification of high-oxidation zones and for input to the equilibrium thermodynamic computer model used in this research. Thermocouples were pushed into saturated and vadose zones of the tailings at depths corresponding to the depths of the BAT sampler tips in both clusters, that is, 0.61, 1.2, 2.1, and 4.9 m. The thermocouples were equipped with a surface connection to which a digital readout device had been attached to obtain the below-surface temperatures. Temperature data were collected at each depth during each sampling trip. No high-oxidation zones were identified from the temperature data.

Head and Pore Pressure

Pore pressures at the B wells and water levels at the P and M wells were measured on each sampling trip prior to collecting samples. At the P and M wells, depth to water was measured with an electronic tape. All positive heads were normalized to sea level. At the B wells, a BAT downhole pressure transducer was used to measure pressure. Prior to installing the sampling vial (figure 4*A*), the pressure transducer (figure 4*B*) was lowered down the access tube and connected hydraulically to the downhole septum with the same type of spring-loaded hypodermic needle used for sampling. The BAT sampler pressure transducer is capable of measuring negative gauge pressures in the vadose zone, in the manner of a tensiometer. Negative gauge pressures are interpreted relative to phreatic surface where water pressure equals atmospheric pressure. Saturated zone B wells were monitored for positive pressure data using the same transducer.

In Situ Moisture and Density

A Campbell-Pacific Nuclear (CPN) 503 moisture density probe was used to measure moisture content and total density over continuous depth profiles at 12 locations on the tailings impoundment. Measurements were taken in June and August 1990 and in March 1991 and were made at 7.6- to 30.5-cm intervals down the access tubes. Of the 12 access tubes used with the CPN moisture density probe at the tailings impoundment, six were BAT sampler access tubes (stainless steel) and six were access tubes (aluminum) installed next to monitoring wells P1, P2, P3, P4, P5, and P6. The CPN 503 moisture density probe has two radioactive sources. The first is a cesium source that emits gamma rays, or photons. The more energy reflected back to the detector, the less the wet (solid plus liquid) density of the soil.

The second radioactive source is composed of americium and beryllium and emits "fast" neutrons. The detector only measures the return of "slow" electrons. A fast neutron must hit something of equal mass, such as a hydrogen nucleus, in order to be slowed to a speed measurable by the neutron detector. The usual substances in soil that contain hydrogen atoms are water, plant organic material (which is primarily water), and hydrocarbons. Therefore, as long as negligible organic material and hydrocarbons exist in the soil, the detector measurement is correlated to moisture content. If the soil is high in boron, there may be an interference problem because the boron nucleus is about the same mass as a hydrogen nucleus. Generally water is the only significant hydrogen source in a soil and boron is rarely present.

Hydraulic Conductivity

The BAT sampler system was designed for in situ point measurements of hydraulic conductivity. The theoretical basis for the test is Hvorslev's solution for a variable head (rising or falling) test for radial flow from an open standpipe. BAT Envitech has adapted the solution for its system (Petsonk, 1984). In particular, incorporation of Boyle's gas law, which relates volume to pressure, is necessary because the testing procedure includes positive or vacuum pressurization, depending upon whether one is doing an outflow or an inflow test. Other adaptations of the formula include corrections for (1) variations in cross-sectional area over the length of the testing apparatus and (2) geometry of the filter tip. BAT Envitech has written software to perform these calculations (Petsonk, 1984).

To perform a hydraulic test, a double-ended sampling vial is used in series with a pressure transducer. The vial is lowered down the access tube to establish hydraulic connection with the filter tip when the spring-loaded hypodermic needle pierces a septum in the vial and another septum at the top of the filter tip. The filter tip must be more permeable than the formation. For this reason, only the completions in the saturated zone with the large-pore-sized thermoplastic tips were used. This way, the filter tip would not limit hydraulic conductivity. When the vial, extension pipe, and pressure transducer unit are charged with a known volume of water and a known volume of positively pressurized gas, the system will force fluid into the tailings pores when hydraulic connection is established (outflow test). If the vial is evacuated, an inflow test is performed. The hydraulic conductivity is calculated repeatedly during the test until a consistent value is reached. However, it is important to ensure that all the water in the vial is not forced into the tailings pores, which would force gas into the tip. To safeguard against this possibility, the BAT software calculates the pressure at which all the water would be forced from the vial and reports a pressure within 80 pct of that value as a safety threshold at which to stop the process.

Groundwater Flow Direction and Velocity

A sodium chloride tracer test was performed to determine the groundwater flow and direction in the colluvium downgradient of the tailings. In this test, a solution of sodium chloride was gravity fed into well M2, and an attempt was made to trace the salt plug downgradient on preestablished grid lines using electromagnetic terrain conductivity equipment. In the initial test, the salt plug was traced only 76.2 m downstream. After that, no conductivity differential could be detected. Because of this short distance from the injection point, the results were deemed too high because of the influence of the gravity injection pressure (about 2.4 m of head) of the sodium chloride solution, and a second test using a different method was used.

In the second test, a borehole-to-surface electrical test was performed. The field test was conducted by personnel from the Department of Geophysical Engineering of the Montana College of Mineral Science and Technology, Butte, MT. For this test, a current electrode was positioned within the borehole at the depth of interest and another placed at electrical infinity. A radial array of equally spaced potential electrodes were placed on the surface. An electrolytic solution was injected into the zone of interest, and as the solution plume was mobilized by the groundwater flow, a direct current from the downhole electrode was introduced into the conductive region. The recorded potential differences measured on the surface were used to compute apparent resistivity, electrical plume length, actual plume length, and groundwater velocity.[4]

LABORATORY DATA COLLECTION

Water Analysis

Water samples brought in from the field were analyzed for total silver, aluminum, barium, boron, cadmium, calcium, copper, iron, lead, magnesium, manganese, nickel, potassium, silicon, sodium, sulfur, and zinc on the ICP at the USBM's Spokane Research Center (SRC) chemistry laboratory. The ICP was used to measure concentrations of the anions sulfate and chloride. Samples were diluted when necessary so that concentrations fell within the linear operating ranges of both the instruments and available standards.

Pore Gas Analysis

A Nuclear-Chicago gas chromatograph (model 5341) was used to measure pore gas concentrations of oxygen and carbon dioxide. Samples were withdrawn by syringe needle from the BAT sampling vial and injected into the gas chromatograph through a septum port.

Column 1 was packed with a 60/80 molecular sieve to measure oxygen, nitrogen, and composite peaks. Column 2 was filled with 80/100 Chromosorb packing material to measure carbon dioxide and composite peaks. Experiments with flow rates of carrier gas, column temperature, and volume of sample injected were performed to yield a range of operation wherein retention times of peaks were consistent, peaks were well separated, and instrument sensitivity was optimized for the concentrations of oxygen and carbon dioxide expected.

The operating parameters used were as follows:

1. Carrier gas volume flow rate for Column 1 (oxygen) was 20 mL/min and 4 mL/min for Column 2 (carbon dioxide).
2. Temperature (both columns) was 30 to 32 °C.
3. Sample injection volume was 40 μL.

The gas chromatograph was calibrated for each session by an analysis of "specialty gases" of known concentrations that were made up to requested mixes. A calibration line was generated for both carbon dioxide and oxygen during each chromatography session using air as one point and either 0.5 pct carbon dioxide in nitrogen or 2.0 pct oxygen in nitrogen as the other point.

Mineral, Chemical, and Physical Properties

Two separate mineral analyses were performed on splits of tailings samples taken in the field. Microscopic examinations were performed by the USBM's Western Field Operations Center, Spokane, WA, to determine the predominant constituents, especially the sulfide content, and a more detailed examination was performed by the U.S. Geological Survey (USGS) to determine sulfate reduction and secondary sulfide formation in the tailings base and subbase material. In the latter tests, polished sections were examined using a reflected-light microscope and a scanning electron microscope (SEM) with energy-dispersive scanning (EDS) capabilities. Photomicrographs were also taken.

Chemical analyses of solid samples below the tailings were performed under contract by IGAL, Inc. A modified sequential extraction procedure was used to help clarify the issue of metal fixation in the sediments below the tailings.

Grain size, specific gravity, plasticity indices, and moisture content [American Society of Testing and Materials (ASTM) designations D422-63, D854-83, D4318-84, and D2216-80, respectively] of the tailings, organic layer below the tailings, and volcanic ash deposit below the tailings were determined at SRC's soils laboratory. A Micrometrics Instrumentation Corp. Sedigraph 5000 particle-size analyzer was used to determine fine grain-size distribution.

Iron and Arsenic Speciation

The speciation of iron and arsenic in an aqueous solution depends strongly on the Eh potential of the system and also on pH (Hem, 1985). Therefore, iron and arsenic speciation is often determined for systems where oxidation is important. Iron speciation was performed on water samples taken from the vadose and saturated zones of the tailings by a USBM chemist.

Arsenic speciation for this research was performed by IGAL, Inc., using a simultaneous extraction procedure developed by Mok and Wai (1987). Although dissolved arsenic concentrations were too low for accurate

[4]Information provided in "A Geophysical Investigation to Determine Groundwater Velocities at a Site in West-Central Washington," by W. R. Sill and K. J. Sjostrom. Final service agreement report to USBM, 1990, 13 pp.

measurement by ICP, trace concentrations exist in the pore water. The Mok and Wai procedure includes an extraction step that concentrates the sample, making it possible to measure concentrations that were originally below detection limits. An atomic absorption graphite furnace was used for the final measurements of elemental arsenic.

Because they are beyond the scope of this RI, results of the iron and arsenic speciation tests are not included.

DATA ANALYSIS AND RESULTS

PRESSURE AND HEAD MEASUREMENTS IN TAILINGS

Figure 5 shows gauge pressure data for the vadose zone, plotted throughout the 4 years of the field study. The pressures range from 0 (i.e., atmospheric pressure) to negative pressures of slightly less than -2 m. The pressures in the vadose zone are closest to atmospheric (saturated) pressure conditions immediately after the spring snowmelt during April and May. The gauge pressure data were measured to chart relative changes in moisture content. The matric suction in the vadose zone becomes less negative as the moisture content increases, reaching zero when the soil is saturated.

Gauge pressure was measured most often during 1988, so that year is best for comparing changes in relative moisture content in the shallow tips with those from the deeper tips at well clusters B1 and B2. As the snow melted in the spring, there was a 1-month lag in peak gauge pressures (and therefore moisture content) between the shallow tip at well B1-4c,[4] (1.2 m) and the deeper tip at well B1-7c (2.1 m). A 1-month lag in peak readings was also discernable between the 1.2- and 2.4-m sampling depths at wells B2-4c and B2-8c.

The 1989 measurements for three of the four vadose zone tips show a distinct increase in pressure, and therefore in moisture content, during the autumn months. This is probably because there was significantly more rainfall in the region during the autumn of 1989 than during the autumn of 1988. It is not obvious why the heads at the tip at well B1-7c did not follow this trend.

Figure 6 shows the head measurements collected in the piezometers and BAT sampler tips in the saturated zone. A seasonal trend is obvious for all samples, whereby heads in the impoundment are highest in the spring after snowmelt and lowest in the winter. A trend in head pressure is apparent among the sampling locations: The most upgradient wells in the tailings (wells P6, P5, P4, and B1-16) have the highest heads, followed by well B2-16, which is farther downgradient in the tailings.

[4]The number following the hyphen is the sample depth in feet from ground level. The actual measurements were made using U.S. customary units.

GAS CONCENTRATIONS IN TAILINGS PORE SPACES

The percentages of oxygen and carbon dioxide in the gas phase in vadose zone pore spaces are presented graphically in figure 7. The approximate depths from ground level at each location are shown in table 2.

Oxygen

In wells at both well cluster B1 and well cluster B2, the concentrations of oxygen decreased with depth (table 4). This finding is similar to the findings of two other studies, one in a sulfidic uranium tailings impoundment (Cherry and others, 1980) and one in sulfidic tailings and alluvium at the Homestake Mine in Lead, SD (Cherry and others, 1986). In the first study (Cherry and others, 1980), oxygen concentrations at depths of 46 cm varied from 9 to 12 pct while oxygen concentrations at depths of 274 cm varied from 1 to 3 pct. In the second study (Cherry and others, 1986), oxygen pore gas profiles were compiled from the vadose zone at two locations in meander deposits of tailings and at two locations in a tailings impoundment. At a depth of 61 cm, concentrations of oxygen varied from 5 to 20 pct, while at a depth of 244 cm, oxygen concentrations varied from 1 to 10 pct.

Table 4.—Average concentrations of oxygen and carbon dioxide as a function of depth in vadose zone pore spaces, percent by volume

Gas	Well cluster B1		Well cluster B2		
	0.6 m	1.2 m	0.6 m	1.2 m	2.4 m
O	20.0	3.1	11.0	3.3	3.0
CO_2	0.0	0.6	0.2	1.1	2.8

The decrease of oxygen with depth indicates that gaseous oxygen is consumed in the vadose zone. Cherry and others (1986) propose that the oxygen consumption is represented by

$$FeS_2 + (7/2)O_2 + H_2O \rightarrow Fe^{2+} + 2SO_4^{2-} + 2H^+ \text{(A)}$$

when ferrous iron (Fe^{2+}) remains in solution, and by

$$FeS_2(s) + (15/4)O_2 + (7/2)H_2O \rightarrow Fe(OH)_3(s) + 2SO_4^{2-} + 4H^+ \quad (B)$$

when iron hydroxide (FeOH) precipitates from excess ferric iron.

Carbon Dioxide

Concentrations of carbon dioxide gas in pore spaces of the vadose zone increase with depth (table 4). These findings are similar to those presented in Cherry and others (1980) in a study of the vadose zone of sulfidic uranium tailings. In this study, carbon dioxide gas concentrations rose from 0.3 to 0.8 pct at depths of 46 cm below the surface to 1.0 to 1.5 pct at depths of 274 cm. Cherry and others surmised that the high carbon dioxide concentrations in the deeper vadose zone were the result of root respiration and the decay of organic matter. This hypothesis offers only a partial explanation for the study site discussed here, which is poorly vegetated by grasses and supports brush and saplings only near the site perimeter. Also, grass root respiration is unlikely to extend to depths of 2.4 m. Another source of carbon dioxide could be microbial respiration (Wood and others, 1993). A 1992 bacterial identification study at the site showed the presence of the sulfate-reducing bacteria *Thiobacillus*, acidophilic heterotrophs, and aerobes at depths of 245 to 520 cm. No carbonates were found in the mineralogical analyses of surface samples, but near the surface, carbonates would have been consumed by acid early in the life of the impoundment.

HYDROLOGIC AND PHYSICAL PROPERTIES OF TAILINGS

The hydrologic, physical, and chemical conditions of the waste impoundment and the sediments immediately beneath the impoundment strongly influence the release and attenuation of contaminants. Water in the saturated tailings comes from precipitation, which seeps downward through the vadose zone; this water then flows into the groundwater below the tailings in the hydraulically connected underlying aquifer. Evidence also suggests groundwater may flow upward into the sediments beneath and possibly into the tailings through fractures in the bedrock below the colluvium.

Grain-Size Distribution

The vertical and horizontal seepage rates of water in the tailings may be influenced by the great reduction in grain size with depth. Grain-size distributions in composite samples at depths between 1.5 and 2.1 m and between 4.9 and 5.8 m near well P3 are shown in figure 8. At well P3 and at least two other locations, a layer of tailings containing silt-sized particles 60 to 90 pct finer than 0.02 mm lies at the base of the impoundment. The higher percentage of fines at increased depth may exist for many reasons.

1. A greater portion of fines in the vadose zone may already have been dissolved.
2. Some portion of the fines in the saturated zone may be precipitated oxidation products from constituents leached out of the overlying material.
3. Some of the fines in the vadose zone may have been cemented into larger, agglomerated particles.
4. Some portion of the fines resulting from weathering in the vadose zone may have been transported downward with time.

The change in grain-size distribution with depth may be correlated to the fact that water samples from the saturated zone have higher concentrations of many key elements than do samples from the vadose zone. Because finer materials have more surface area available for chemical interaction, which leads to more rapid dissolution, highly soluble fines in the vadose zone have probably already been dissolved.

It is important to note that the increase in the percentage of fines with depth in the impoundment will reduce hydraulic conductivity with depth.

Density and Moisture

Analysis of the data from the moisture and density profiles shows four distinct zones of moisture in and below the tailings. These zones are the vadose zone, the capillary fringe zone, the saturated zone in the tailings, and the saturated organic layer-silt zone below the tailings. The average in situ moisture, expressed as weight of water per weight of dry solids, of each zone is summarized in table 5. Based on moisture content, the vadose zone ranges from 1.5 m deep at well P6 to 2.7 m at well P2. This zone was about 34 pct saturated in June and about 30 pct saturated in August. The capillary fringe zone, identified as the zone above the water table in which the moisture content equals or exceeds the lowest moisture content reading below the water table, ranges from 0.9 to 1.8 m above the water table. Evaporation effects result in upward capillary flow and a reduction of average moisture content in the vadose zone between June and August. Evaporation effects could be seen to a depth of about 1.5 m, after which very little, if any, moisture changes occurred between spring and late summer.

Obtaining in situ moisture and density data at various locations allows the identification of zones or layers with

Table 5.—Average moisture content in various zones in and below tailings, percent[1]

Well ID	Vadose zone June	Vadose zone August	Capillary fringe June	Saturated zone June	Organic silt zone[2] June
P1	9.9	9.7	ND[3]	ND	ND
P2	12.6	11.4	27.4	26.5	ND
P3	11.1	9.5	26.5	27.1	46.9
P4	9.4	8.1	27.6	27.7	ND
P5	8.0	6.7	26.1	26.1	ND
P6	8.6	7.5	22.1	21.9	ND
B1-4	11.6	9.1	ND	ND	ND
B2-4	10.2	10.4	ND	ND	ND
B1-7	9.1	8.3	ND	ND	ND
B2-8	12.1	10.5	ND	ND	ND
B1-16	9.4	7.5	26.1	26.1	ND
B2-16	12.4	10.9	([4])	29.4	ND

[1]Moisture content as a percentage is defined as the weight of water divided by the weight of dry solids times 100. Moisture contents in the perched water zones identified in wells P1, P2, P5, B1-16, and B2-16 are not included in the average.

[2]The organic-silt zone is a zone of material below the tailings. This zone has higher moisture content and lower density than the tailings.

[3]ND No data. In all cases, the access tubes for in situ moisture measurements were not driven to these zones at these wells.

[4]All moisture contents above the water table were less than any measured below the water table.

excessively high or low moisture contents or densities. These zones could indicate perched water, different material types, layers, or other anomalies that might influence the downward migration of contaminants.

Tailings Layering

Physical and chemical heterogeneities are not uncommon in milled tailings impoundments, and this study site was no exception. Spatial variations in physical property values in tailings piles can result from differences in ore mineralogy, short-term changes in milling processes, depositional history, or weathering after deposition. The tailings at the study site are layered, and layers differ on the basis of color, texture, grain size, density, and moisture content. The influence of these physical heterogeneities on water chemistry and water movement may vary depending on locality.

The moisture content and density profile in figure 9 at well B2-4c shows an isolated layer of high moisture and low density in the vadose zone about 46 cm below the surface. A tailings sample (B-2) was collected from the surface to a depth of 61 cm through this layer near well B2-4c and examined. In the middle of the sample was a hardpan layer. The hardpan sample did not soften or decompose when it was exposed to water or concentrated acid in the laboratory. The tailings above the hardpan appeared to be more oxidized, much lower in moisture content, and coarser in grain size than the tailings below the hardpan.

The grain-size distributions of samples above and below the hardpan are shown in figure 10. A dramatic reduction in grain size between the top and bottom of sample B-2 can be seen. The explanation of this large difference, although not clear, possibly relates to the chemical and physical weathering of particles, or perhaps the cementation of particles above the hardpan but not below.

The hardpan in sample B-2 divides coarse and fine tailings, probably restricts the downward flow of atmospheric oxygen, and reduced water seepage velocity. This has two effects on contaminant migration and attenuation. First, because oxidation is required in the acid-generation process, acid generation below the hardpan is slowed. Second, the hardpan appears to influence pore water quality. The data in table 6 show that concentrations of most metals in solution increase with depth in well cluster B1 but decrease with depth in well cluster B2. This difference may be related to the hardpan within the well cluster B2. Because the seepage velocity is lower through the hardpan and the finer material below, the H^+ ion may be given enough residence time to consume the neutralizing agents resulting from silicate and aluminosilicate mineral dissolution, resulting in more sulfide oxidation products in solution at the 1.2-m level. At well cluster B1, where there is no hardpan, the sulfide oxidation products and H^+ appear to move freely downward, resulting in higher metal concentrations and lower pH with depth.

Similar findings were reported at the Heath Steele Mine's tailings dump in New Brunswick (Boorman and

Table 6.—Average constituent concentrations in well clusters B1 and B2, parts per million

Constituent	Well cluster B1			Well cluster B2		
	1.2 m	2.1 m	4.8 m	1.2 m	2.4 m	4.8 m
pH	3.76	3.73	3.49	3.16	3.74	3.89
Element:						
Al	55	582	2,479	552	501	147
Ca	96	466	531	428	451	458
Cu	15	113	16	137	102	50
Fe	75	811	12,864	2,013	1,194	763
K	12	4	59	2	6	4
Mg	93	372	2,429	329	416	155
Mn	2	9	159	8	12	8
Na	6	36	38	17	29	17
Pb	0.20	0.40	5	0.70	0.70	2
S	366	2,303	15,614	3,013	2,531	1,317
Si	70	49	41	100	34	32
Zn	7	46	1,539	140	178	78

NOTE.—Averages are calculated on analysis of 14 to 16 different water samples taken over 2 years. Well cluster B2 is about 46 m southeast of well cluster B1. Depths are from ground level to the center of the porous sampling tip.

Watson, 1976). The Canadian researchers describe the hardpan as being 5 to 10 cm thick, lying 25 to 50 cm below the surface between the oxidation zone and the reduction zone, and consisting of tailings cemented with iron hydroxides, oxides, and gypsum. In addition, the hardpan contained high levels of copper and zinc that precipitated as a result of chemical reactions. In 1985, the pore water chemistry at the Heath Steele tailings dump was found to be about the same as it was in 1976. The consistency of the geochemistry over the 9-year period was attributed to the effect of the hardpan (Blowes and others, 1987).

Hydrologic Characteristics

Based on three-point solutions of average potentiometric elevations among wells P4, P5, and P6, and among wells P4, P5, and P1, the direction of the horizontal component of flow from well P5 was determined (shown by an arrow on figure 3). The potentiometric surface in the direction of flow dips about 0.78 m over a distance of about 140 m between well P6 and well P1, resulting in a relatively flat horizontal hydraulic gradient of 5.6×10^{-3} m/m. This measurement was compared with an even flatter horizontal gradient of 6.0×10^{-4} m/m from well P5 to well P4. Downgradient horizontal hydraulic gradients were 3.9×10^{-2} m/m and 2.2×10^{-2} m/m between the shallowest piezometers of well M2 and well M4 and between the shallowest piezometers of well M4 and well M5, respectively. Spacings between wells in the saturated tailings were inadequate for determining the vertical component of the hydraulic gradient. However, in the multiple-completion background and downgradient wells, the vertical component of flow direction and vertical hydraulic gradients were determined at wells BKG, M2, M4, and M5 and are shown in table 7. In situ measurements determined with the BAT system indicated an average hydraulic conductivity in the saturated tailings of 2×10^{-5} cm/s.

Other hydrologic properties that affect downgradient contaminant transport at the study site are advection and dispersion. Based on the difference in estimated horizontal groundwater flow velocities (2.7×10^{-4} m/d in the saturated tailings and 0.6 m/d in the downgradient aquifer) (Stewart and others, 1990),[5] the transport of contaminants by flowing groundwater (advection) is much greater in the downgradient aquifer than in the tailings. Because the shallow aquifer at this site is narrow, transverse dispersion is probably constrained and only longitudinal dispersion occurs freely.

From a positive environmental aspect, the decrease in hydraulic conductivity and the relatively flat gradient through the tailings results in a very slow and naturally controlled release of soluble metals from the tailings into the downgradient environment, allowing for maximum dilution and chemical precipitation. However, the long periods over which the pore water is in contact with the tailings facilitates long-term mechanical weathering and allows completion of slower kinetic chemical reactions.

The vertical component of gradient in wells BKG and M5 indicates an upward flow direction between the intermediate and the shallow completions in the spring and late summer, indicating a more continuous recharge in the shallow alluvium. At well M2, the direction of the vertical flow component appears to go upward in the spring and downward in late summer. At well M4, the flow direction is downward even during the spring recharge, possibly indicating discharge into a bedrock fracture.

[5]See footnote 3.

Table 7.—Vertical component of hydraulic gradient and flow direction for background and downgradient multiple-completion wells.

Well ID	Season	Vertical flow direction	Horizontal gradient, m/m
BKG-6→BKG-20	Spring	Upward	0.016
BKG-6→BKG-20	Late summer	Upward	0.015
BKG-20→BKG-43	Spring	Downward	0.002
BKG-20→BKG-43	Late summer	Downward	0.001
M2-4→M2-6	Spring	Upward	0.004
M2-4→M2-6	Late summer	Downward	0.007
M2-6→M2-12	Spring	Upward	0.032
M2-6→M2-12	Late summer	Upward	0.002
M4-5→M4-7	Spring	Downward	0.038
M4-5→M4-7	Late summer	Downward	0.144
M4-7→M4-10	Spring	Downward	0.022
M4-7→M4-10	Late summer	Downward	0.089
M5-4→M5-23	Spring	Upward	0.092
M5-4→M5-23	Late summer	Upward	0.116
M5-23→M5-53	Spring	Downward	0.133
M5-23→M5-53	Late summer	Downward	0.132

PROPERTIES OF SEDIMENTS BELOW TAILINGS

Hydrologic and Physical Characteristics

Solid samples collected during initial drilling clearly indicate that the tailings were deposited in a shallow, swampy lake basin. Below the tailings is an organic-rich silt layer 30 to 60 cm thick containing abundant snail shells. Below this layer is a layer of silt 3 to 4.5 m thick. Atterburg limit determinations indicate the silt has a liquid limit of 66.7 pct and a plasticity index of 7.2. According to the Unified Soil Classification System (U.S. Bureau of Reclamation, 1963), this material is in the MH soil classification group, indicating it to be inorganic silts, micaceous or diatomaceous fine sandy or silty soil (elastic silt). MH soils are generally very absorptive, have low dry strength, and exhibit slow dilatancy. An EDS spectrum of this material showed abundant silicon and detectable amounts of aluminum, potassium, calcium, and iron. In addition, secondary kaolinite minerals could be present. Kaolinite is formed by weathering or hydrothermal alteration of aluminum silicates, particularly feldspar (Klein and Hurlbut, 1985).

Figure 11 illustrates that at a depth of 5.8 m, the silt zone has a lower density than the tailings and contains 1.7 times more water by weight per unit volume than the tailings. The average water content and bulk density of the silt below the tailings at well P3 (measured in June 1989) were 46.9 pct by weight and 1.17 g/cm^3, respectively. By comparison, the average water content and bulk density in the saturated tailings at well P3 were 27 pct and 1.60 g/cm^3, respectively. Using the average bulk densities measured in June 1989 and the average specific gravity of solids in each zone (determined by specific gravity tests on samples collected at the study site), the porosity for the saturated tailings was 42.8 pct and 54.4 pct for the saturated silt. These measurements were consistent with the presence of the organic material underlain by lacustrine silt, as identified during drilling.

Mineral Analysis

To get a better understanding of the fate of the concentrated contaminants that exist in the tailings, a detailed mineral analysis of the organic-rich layer and other sediments below the tailings was undertaken. This work was performed under contract by Dr. Charles Alpers of USGS. The objective of the analysis was to determine if the organic-rich layer was causing any attenuation of metals migrating from the tailings. To investigate this possibility, evidence was sought for sulfate reduction and secondary sulfide formation in the organic-rich layer. Several samples of the organic-rich material were prepared and examined using a reflected-light microscope and SEM with EDS capabilities. A description of each sample observed by Dr. Alpers is found in appendix C. The following is a summary of Dr. Alpers' report to the USBM:

> Sediment samples from the field site were scanned in two batches, one collected during 1988, the other during 1990. The 1988 samples (eight in all) consisted of dried powders taken from various depths while drilling monitoring wells P 4, P 5, and P 6. Polished sections were prepared of the fine-grained fraction of these samples by first screening the samples at 60 mesh and then mounting the fine-sized fraction in 1-in-diam epoxy blocks. These polished sections were examined using a reflected-light microscope and a SEM with EDS capabilities.

The 1990 samples were delivered in frozen state as sections of intact, split barrel samples collected while drilling monitoring wells B2A, P3A, and P3C. The cores arrived wrapped in cellophane and aluminum foil. The sampling strategy was to sample the organic-rich layer near to the tailings-sediment interface in each core as well as other locations at approximately 30-cm intervals. These samples were dried in an oven overnight at about 90° C, and then were mounted on aluminum disks for SEM analysis. No polished sections were prepared for the 1990 samples.

Results indicate the organic-rich layer is host to numerous framboidal spheres composed of Fe and S and assumed to be pyrite. This indicates a strong reducing environment, where bacteria are able to reduce aqueous sulfate to aqueous hydrogen sulfide, in the presence of sufficient iron to produce solid iron sulfides. This process is only possible where the sulfate-reducing bacteria have sufficient sources of aqueous sulfate, organic carbon, iron, and nutrients, such as ammonia and phosphate (Goldhaber and Kaplan, 1982).

Rates of sulfate reduction are highly variable; complete sulfate removal in marine sediments can take hundreds of years (Goldhaber and Kaplan, 1982). In some marine sites of rapid burial, significant sulfate reduction can take place in years to tens of years (Chanton, Martens, and Goldhaber, 1987). If none of the crucial ingredients are limiting, sulfate reduction can proceed in relatively fast rates, and it would be possible to produce the observed framboids in their entirety after the disposal of the tailings in the 1930's and following years. However, it is more likely that the framboidal pyrite was present prior to the introduction of the tailings.

One possibility with respect to metal mobilization at this tailings site is that the reducing environment represented by the neo-formed sulfides could be a site of metal fixation. Thus, metals leached from the oxidized tailings could be fixed in the organic-rich, sulfide-bearing layer.

However, other than the pyrite framboids, no secondary base-metal sulfides were observed. If metals leached from the tailings had been actively reduced, coatings on the framboids consisting of minerals such as chalcocite, covellite, and digenite (Cu-sulfides) or sphalerite (Zn-sulfide) might be expected. These minerals are commonly observed in zones of sulfide enrichment, formed below the water table in actively oxidizing base metal sulfide systems (Alpers and Brimhall, 1989). Given that no such secondary base-metal sulfides were observed, it seems that any metals that are being fixed because of flow through the sulfide-rich organic layer are indeed being fixed by adsorption onto organic material.

Chemical Analysis

To help clarify the issue of metal fixation in the sediments below the tailings, chemical analyses using a modified sequential extraction procedure were performed on samples collected near the base of the tailings and up to 150 cm below the base. The samples were obtained during the 1990 drilling of wells P3A, P3C, and P2A and were taken at 15 to 61 cm below the tailings in the organic layer (P3A), 122 cm below tailings and below the organic layer (well P3C), 15 to 61 cm above the base of tailings and above the organic layer (well P2A), and 15 to 61 cm below the tailings in the organic layer (well P2A). These tests were performed, under contract, by IGAL, Inc.

In the sequential extraction procedure used, five fractions were chosen that were likely to have been affected by various environmental conditions. These were fraction 1, exchangeable; fraction 2, bound to carbonates; fraction 3, bound to iron and manganese oxides; fraction 4, bound to organic matter; and fraction 5, bound to sulfides. Six elements (silicon, aluminum, iron, manganese, copper, and lead) in all five fractions were analyzed by atomic absorption spectrometry. Calcium and magnesium were determined by ICP analysis.

Results of the sequential extraction tests are shown in appendix D. These results indicate that solid-phase lead and copper were not present to any great extent in the organic-rich layer or silt zone below the tailings, but were present in the base of the tailings. Lead was bound primarily in the sulfide-residual and oxide phases at the tailings base, and copper was bound primarily in the sulfide-residual phase at the tailings base. Both did not appear to be remobilizing below the tailings. Solid-phase iron and manganese were abundant in the organic-rich layer and silt zone below the tailings. In the organic-rich layer, iron was present in the oxide, sulfide, and carbonate phases, with the oxide phase being the most dominant. A smaller, but significant, amount of iron was bound to organic matter in this layer. Iron was bound primarily to sulfides in the tailings base and to carbonates in the silts below the organic-rich layer. Manganese was also bound to carbonates. These data indicate that some of the reduction of iron and manganese in the pore water of the organic-rich layer and silts below the tailings is due to iron carbonate and manganese carbonate precipitation.

Although calcium and magnesium were present in several phases in the organic-rich zone, they appeared most abundant in the silts below the organic-rich layer, primarily in the carbonate form. Carbonate dissolution in this zone is probably the major source of calcium and magnesium in the gravel aquifer downgradient from the tailings impoundment.

WATER QUALITY

Water quality data were collected upgradient from the tailings (BKG wells), from the vadose and saturated zones of the tailings (B and P wells), from below the tailings, and from different distances downgradient of the tailings (M wells). The results of each sampling trip are shown in appendix B, and the averages are summarized in tables 8 through 10. Systematic errors, such as erratic measurements in all samples from one collection trip, do not appear. At most, two samples in one sample run were anomalous, and even in these instances, it was impossible to determine whether the samples were mislabeled, contaminated, misdiluted, or improperly analyzed by the ICP. Because no systematic reasons for rejection were identifiable, rejection decisions were made on a statistical basis. All data outliers were rejected on the basis of the Grubbs test (Taylor, 1990) using $\alpha = 0.001$. This very small value of α ensured that only the most extreme data were rejected. The data were grouped by element at each sampling location across all sampling trips for detection of outliers.

Arsenic data are not reported because they were found to be below or near detection limits for the ICP, and the ICP does not provide accurate measurements of arsenic near the detection limit.

Many of the variations in concentration discussed in the following sections are described in terms of mineralogical solubility controls, which are briefly mentioned here because they may influence the relative concentrations of various constituents. Discussions will be limited to values from the tailings and Quaternary colluvium only. Values from the bedrock will not be discussed, except where there appears to be an effect of bedrock waters on tailings and shallow colluvium waters. Values from sediments immediately below the tailings are discussed in the section on "Water Quality Below Tailings."

Eh and pH

There is no apparent seasonal (temporal) variation for either Eh or pH. The vadose zone is generally more acidic (with lower pH values) than the saturated zone. Similarly, the Eh values in the vadose zone are consistently oxidizing, whereas the saturated zone waters are more variable and less oxidizing. These findings were expected. Because the vadose zone has oxygen gas in the pore spaces, sulfides would be oxidized, producing sulfuric acid, which causes pH to decrease. As the waters percolate deeper, however, less oxygen but more (fresh) solids are available to react with the acid. Thus, Eh is likely to decrease and pH to increase. In the vadose zone, average pH and Eh are 3.6 and 540 mV, respectively, and in the saturated zone these values are 4.2 and 450 mV, respectively. Downgradient at well M5-4, pH gradually increases to 7.1, which is the background level shown at well BKG-6. This is a result of hydrogeochemical reactions, dilution, and dispersion. Downgradient, Eh averages 360 mV at well M5-4, a value that is only slightly lower than the average background Eh of 400 mV at well BKG-6.

Table 8.—Arithmetic means of analysis and chemical characteristics of tailings pore water from vadose zone

	B1-4	B1-7	B2-4	B2-8	Average
Eh, mV	540	540	560	520	540
pH	3.80	3.70	3.20	3.70	3.60
Element, mg/L:					
Al	59.00	450.00	650.00	430.00	400.00
B	0.25	2.10	7.10	2.90	3.10
Ba	0.02	0.02	0.01	0.01	0.02
Ca	100.00	450.00	400.00	460.00	350.00
Cd	0.02	0.20	0.98	1.10	0.58
Cu	12.00	98.00	140.00	91.00	85.00
Fe	80.00	700.00	1,900.00	1,000.00	920.00
K	10.00	4.00	2.70	5.90	5.70
Mg	90.00	320.00	320.00	360.00	270.00
Mn	2.00	8.30	8.10	10.00	7.10
Na	8.20	37.00	15.00	28.00	22.00
Ni	0.30	0.32	0.34	0.45	0.35
Pb	0.21	0.34	0.61	0.63	0.45
S	350.00	2,000.00	3,000.00	2,200.00	1,900.00
Si	63.00	48.00	94.00	33.00	60.00
Zn	7.20	40.00	139.00	160.00	87.00

Table 9.—Arithmetic means of analysis and chemical characteristics of tailings pore water from saturated zone

	P4	P5	P6	B1-16	B2-16	Average
Conductivity, μS/cm	7,850	6,953	>10,000	NM	NM	NM
Eh, mV	390	470	400	490	500	450
pH	4.70	4.10	4.70	3.50	3.90	4.20
SO_4, mg/L	23,000	NM	NM	39,000	3,900	NM
Element, mg/L:						
Al	70.00	990.00	18.00	2,300.00	140.00	700.00
B	22.00	19.00	64.00	28.00	2.10	27.00
Ba	0.02	0.04	0.03	0.01	0.01	0.02
Ca	440.00	430.00	540.00	500.00	460.00	474.00
Cd	2.50	4.50	0.04	17.00	1.00	5.00
Cu	9.80	290.00	26.00	16.00	48.00	78.00
Fe	8,800.00	7,800.00	22,000.00	11,000.00	740.00	10,000.00
K	76.00	31.00	71.00	54.00	4.20	47.00
Mg	1,500.00	1,100.00	4,000.00	2,000.00	150.00	1,800.00
Mn	170.00	63.00	250.00	140.00	7.80	130.00
Na	45.00	18.00	24.00	39.00	17.00	29.00
Ni	1.90	1.20	4.40	3.20	0.19	2.20
Pb	2.40	3.20	5.00	5.20	2.20	3.60
S	7,900.00	8,000.00	21,000.00	13,000.00	1,300.00	10,000.00
Si	30.00	35.00	17.00	40.00	29.00	30.00
Zn	840.00	550.00	3,200.00	1,300.00	74.00	1,200.00

NM Not measured or only one measurement made.

Sulfur, Iron, and Manganese

Iron and sulfur are presented together because they are the predominant dissolved constituents in all tailings water samples and the primary constituents of pyrite. The dissolved iron in this system is in the form of ferrous and ferric iron. Sulfate concentrations measured by IC for several sample runs verify the assumption that all dissolved sulfur measured by ICP is in the form of sulfate. While sulfate is the predominant anion in the tailings pore waters, small concentrations of chloride were also detected. Manganese is presented with sulfur and iron because manganese behaves in a manner similar to iron chemically and mineralogically. As is iron, manganese is influenced by redox in weathering environments (Hem, 1985); downgradient of the low-pH zone, manganese should form oxides that scavenge other metals that are included subsequently in the oxide mineral matrix.

The solubility of iron and sulfur minerals is controlled by Eh and pH. Iron and sulfur concentrations with depth are nearly identical, which reflects their high correlation as a result of pyrite oxidation. Concentrations are generally higher in the saturated zone than in the vadose zone. In the vadose zone, the mean concentrations of iron and sulfur are 920 and 1,900 mg/L, respectively. In the saturated zone, the mean is 10,000 mg/L for both constituents. In the acidic environment of the impoundment, the high concentrations of iron and sulfur are probably attributable to the solubility of metal sulfate minerals such as melanterite, which is a ferrous species, and the jarosites. The pale green color of the tailings pore water samples verifies the dominance of ferrous iron. In the impoundment, most of the manganese will occur as the manganous (Mn^{2+}) and sulfate (SO_4^{2-}) ion pair. The mean values for manganese in the vadose and saturated zones of the tailings are 7.1 and 130 mg/L, respectively.

Downgradient, sulfur attenuates to only 390 mg/L at well M5-4, a level four times background (92 mg/L at well BKG-06). However, iron attenuates rapidly to 0.64 mg/L at well M5-4, a level below that of background (0.77 mg/L at well BKG-6). The difference in attenuation between the two is caused by the species that control solubility. In neutral-pH environments, such as found downgradient of the study site, the concentration of sulfur is often controlled by gypsum solubility, whereas downgradient concentrations of iron are probably controlled by solubility of ferric species (goethite and ferrihydrite). Manganese attenuates to a mean of 0.42 mg/L at well M5-4, a level that is 14 times background (0.03 mg/L at well BKG-6), but well below the mean impoundment value of 85 mg/L. This reduction is probably controlled by coprecipitation with iron and by manganese-carbonate solubility.

Table 10.—Arithmetic means of analysis and chemical characteristics of downgradient and background water

	BKG-6	BKG-20	BKG-43	M1-2	M1-3	M1-8	M2-4	M2-6	M2-12	M3-10	M4-5	M4-7	M4-10	M5-4	M5-23	M5-53
Conductivity, μS/cm	490	960	930	1,000	1,200	1,300	1,600	1,400	1,200	830	2,400	1,800	2,600	1,800	450	450
Eh, mV	400	210	220	410	250	190	370	350	280	200	410	360	280	360	340	170
HCO_3^{-1}, mg/L	340	NM	NM	NM	505	647	240	NM	NM	NM	437	543	NM	421	176	128
pH	7.10	7.50	7.60	5.90	7.10	7.10	6.40	6.50	6.90	7.20	6.80	6.90	7.10	7.10	7.60	8.40
SO_4^{-2}, mg/L	230	310	300	2,500	720	720	870	880	600	460	2,200	1,900	1,900	1,000	220	160
Element, mg/L:																
Al	0.21	0.23	0.30	0.84	0.34	0.38	0.37	0.36	0.26	0.25	0.38	0.38	0.37	0.34	0.36	0.34
B	0.18	4.30	5.00	0.63	0.41	0.43	0.17	0.20	0.51	0.31	0.32	0.37	0.46	0.29	1.20	2.40
Ba	0.03	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.06	0.08	0.05
Ca	140.00	47.00	36.00	480.00	260.00	290.00	290.00	280.00	270.00	220.00	610.00	625.00	530.00	390.00	74.00	12.00
Cd	<0.01	<0.01	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cu	0.05	0.05	0.05	0.24	0.08	0.05	0.05	0.07	0.07	0.05	0.18	0.13	0.10	0.08	0.06	0.05
Fe	0.77	0.93	0.64	260.00	14.00	13.00	1.20	4.50	1.40	3.40	0.57	1.60	2.70	0.64	1.30	0.52
K	2.30	2.30	2.60	14.00	3.50	3.20	6.50	6.20	2.20	2.20	8.70	2.00	5.10	4.30	0.70	0.20
Mg	29.00	27.00	19.00	280.00	79.00	71.00	96.00	91.00	66.00	37.00	210.00	180.00	140.00	120.00	11.00	0.50
Mn	0.03	0.15	0.03	31.00	5.60	3.50	22.00	22.00	4.70	2.00	1.90	1.00	1.10	0.42	0.11	0.03
Na	20.00	180.00	210.00	23.00	72.00	31.00	25.00	25.00	45.00	23.00	30.00	59.00	210.00	53.00	100.00	120.00
Ni	<0.05	<0.05	<0.05	0.21	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Pb	0.06	0.06	0.07	0.11	0.07	0.09	0.08	0.07	0.07	0.07	0.09	0.09	0.08	0.07	0.06	0.06
S	92.00	110.00	210.00	920.00	290.00	260.00	290.00	290.00	270.00	140.00	730.00	700.00	650.00	390.00	95.00	58.00
Si	14.00	10.00	10.00	23.00	9.30	11.00	14.00	14.00	12.00	11.00	19.00	16.00	21.00	15.00	13.00	6.40
Zn	0.11	0.08	0.07	56.00	0.38	0.14	0.21	0.16	0.08	0.09	0.39	0.12	0.12	0.16	0.14	0.09

NM Not measured.

Lead and Nickel

Based on electronic configuration of their atoms, lead is a representative element and nickel is a transition element. Lead generally has a low solubility and is only superficially attacked by dilute sulfuric acid. Lead concentrations may frequently be less than that predicted by solubility conditions for a given pH. Hem (1976) believes much of this discrepancy can be attributed to cation exchange. However, the strong sorbtion characteristics of lead may also be a contributing factor. Nickel often substitutes for iron and consequently its major source in the tailings is probably pyrite. The mobility of both elements tends to be low and controlled by coprecipitation with iron and manganese oxides. The mean values of lead and nickel in the vadose zone of the study area are 0.45 and 0.35 mg/L, respectively, and in the saturated zone are 3.6 and 2.2 mg/L, respectively. Downgradient, lead attenuates to 0.07 mg/L at well M5-4, very near background levels of 0.06 mg/L at well BKG-6. Nickel levels are at or below background levels of 0.05 mg/L at well M5-4.

Cadmium and Zinc

Cadmium is a common replacement cation for zinc in the sphalerite lattice and would be released with zinc during dissolution within the impoundment. Both are soluble in dilute acidic, oxidizing conditions, such as in the impoundment, and can have rapid reactions with these acids when associated with other, less reactive metals as a result of couple action. Both zinc and cadmium precipitate as hydroxides and carbonates in the presence of equivalent amounts of alkali or are adsorbed by the soil solid phase. The mean values of cadmium and zinc in the vadose zone of the tailings are 0.58 and 87 mg/L, respectively, and in the saturated zone are 5.0 and 1,200 mg/L, respectively. Downgradient concentrations at well M5-4 are less than 0.01 and 0.09 mg/L, respectively, both equal to or below background concentrations.

Barium and Boron

Boron is a common trace constituent in feldspars and micas, and the borate ions are most soluble under acidic, oxidizing conditions, such as in the impoundment. The high boron concentrations found in the impoundment are unusual and probably result from the acid dissolution of borosilicates. Unlike boron, barium in the sulfate form is extremely insoluble and will tend to precipitate in the tailings. This is evidenced by the low concentrations of barium in the tailings pore water samples and by the abundance of barite in the solid tailings as determined by SEM. Mean concentrations of boron and barium in the vadose zone are 3.1 and 0.02 mg/L, respectively, and in the saturated zone are 27 and 0.02 mg/L, respectively. Downgradient, boron attenuates to 0.29 mg/L at well M5-4, slightly higher than background levels of 0.18 mg/L at well BKG-6. Barium levels stay relatively constant, with an average of 0.06 mg/L at well M5-4 and an average background level of 0.03 mg/L at well BKG-6.

Aluminum and Copper

These metals are presented together because they exhibit slightly different behaviors than the metals discussed previously. The behavior of aluminum is unique because saturated zone concentrations (with the exception of concentrations from well B1-16) are approximately equal to those in the vadose zone. Below pH 4.5, aluminum concentrations are limited by solubilities of basic aluminum sulfate minerals. Between pH 4.5 and 4.9, jurbanite may limit solubility. Aluminum solubility in waters of pH greater than 4.9 is reported to be controlled by the gibbsite solubility product (Nordstrom and Ball, 1986), and gibbsite is more likely to precipitate with increasing pH. Gibbsite solubility may be the factor that causes aluminum to have a relatively constant concentration across the transition zone. The mean concentration of aluminum in the vadose zone is 400 mg/L and in the saturated zone is 700 mg/L. Downgradient at well M5-4, the mean value is 0.34 mg/L, slightly higher than the mean background level of 0.21 mg/L at well BKG-6.

Copper has concentrations similar to those of aluminum in the saturated and vadose zones of the tailings. In view of the fact that the tailings are from a copper mine, the concentrations of copper are extremely low. Hem (1985) notes that if copper concentrations are less than those predicted by pH-Eh diagrams (thermodynamic chemical equilibria), then the lower concentrations are probably caused by the coprecipitation of oxides (such as iron or manganese oxides) or adsorption onto mineral surfaces. This appears to be the case at the study site. Assays have shown amounts of solid copper in the 1,000 to 3,000 ppm range in the vadose and saturated portions of the tailings, but generally below the zone of oxidation. The mean concentration of dissolved copper in the pore water of the vadose zone is 85 mg/L and in the saturated zone is 78 mg/L. Mean downgradient level of copper at well M5-4 is 0.08 mg/L, which is only slightly higher than the mean background level of 0.05 mg/L at well BKG-6.

Calcium and Magnesium

Calcium and magnesium are alkaline-earth metals. Anorthite from the tailings and calcium carbonate from the snail shells in the lake sediments below the tailings are the possible sources of calcium at the field study site. The behavior of calcium in sulfate-dominated systems is generally governed by the gypsum solubility product. Magnesium is similar to and tends to mimic the chemical behavior of calcium. Most magnesium minerals do not precipitate unless considerably supersaturated. The major source of magnesium in the impoundment is probably chlorite, common in propyllitized andesite.

Calcium and magnesium have comparable concentrations and behavior in the vadose zone, but in the saturated zone their behaviors diverge. That is, calcium concentrations do not increase appreciably in the saturated zone, whereas magnesium concentrations do. In the vadose zone, average pore water concentrations of calcium and magnesium are 350 and 270 mg/L, respectively. In the saturated zone, the averages are 474 and 1,800 mg/L, respectively. Calcium increases downgradient, but then decreases to 390 mg/L at well M5-4. Magnesium levels at well M5-4 attenuate only to 120 mg/L. Background levels of calcium and magnesium at well BKG-6 average 140 and 29 mg/L, respectively.

Potassium and Sodium

Potassium is probably derived from dissolution of potassic feldspars and sodium from the dissolution of the albite feldspars. Sodium is an ion of small radius and is strongly hydrated. Once sodium enters into solution, there are no dominant precipitation reactions that control its solubility (Hem, 1985). Potassium may be controlled by being incorporated into clay structures and adsorbed (Hem, 1985). Potassium concentrations are higher in the saturated zone than in the vadose zone, like the majority of other cations, but sodium concentrations are not. Mean concentrations of potassium and sodium in the vadose zone are 5.7 and 22 mg/L, respectively, and in the saturated zone are 47 mg/L and 29 mg/L, respectively. Downgradient at well M5-4, potassium attenuates to 4.3 mg/L, slightly above background concentrations of 2.3 mg/L at well BKG-6. Sodium concentrations increase downgradient to an average of 53 mg/L at well M5-4, about 2.5 times higher than the background level of 20 mg/L at well BKG-6.

Silicon

Silicon is often referred to as the dissolved oxide species silica (SiO_2) in natural waters, but its actual form is usually one of the more hydrated uncharged ions based on the tetrahedron form SiO_4^{4-}, such as silicic acid (H_4SiO_4).

The average concentration of silicon in the vadose zone pore water is 60 mg/L and in the saturated zone is 30 mg/L. Silicon is the only dissolved constituent for which average concentrations are higher in the vadose zone. Silicon solubility at cool temperatures is generally controlled by the mineral referred to as amorphous silica (Hem, 1985) and may also be controlled by such aluminosilicate minerals as kaolinite and montmorillonite. Silicon concentrations in the two zones appear to differ in correlation to the different redox status, but the thermodynamics of silica suggest that the differing concentrations are not a result of acid dissolution. It is possible that the higher silicon concentration in the vadose zone results from the sparse vegetation; Drees and others (1989) note that production of organic complexes increases the dissolution rate of silica by complexing monosilicic acid. Drees and others also note that the dynamic changes in moisture content caused by wet-dry cycles may influence silica concentration more than other processes, such as dissolution-precipitation reactions. In downgradient well M5-4, the mean concentration is 15 mg/L, or nearly equal to the average background concentration at well BKG-6 of 14 mg/L.

Water Quality Below Tailings

To determine contaminant concentrations below the tailings, three additional wells were drilled in the vicinity of well P3. These wells, P3A, P3B, and P3C, were drilled to 6.5 m (about 30 cm below the tailings), 5.9 m (base of the tailings), and 7.1 m (about 90 cm below the tailings), respectively. Well P3 (drilled in 1987) was drilled to 9.1 m, about 3 m below the tailings. Average concentrations of metal ions in these wells are shown in table 11.

Fifty years after the tailings were deposited onto the silts, concentrations of every element determined (except barium) were lower in the pore water of the silts 30 to 90 cm below the tailings than in the pore water at the base of the tailings (table 11) and much lower than in the pore water in the core of the saturated tailings (table 9). This could mean that water with very low concentrations of measured constituents is flushing the porous silts and perhaps the base of the tailings. At the P3 cluster wells (P3, P3A, P3B, and P3C), the vertical component of gradient indicated a weak upward flow in the lacustrine sediments during the spring, a time of high groundwater recharge.

Another explanation for low metal concentrations in the silts below the tailings is that tailings pore water may not be seeping into the silts to any significant degree, but may flow horizontally as a result of lower hydraulic conductivity at the base of the tailings. If substantial horizontal flow does occur at the base of the tailings, then pore water from the tailings may eventually enter the gravels at the edges of the impoundment, bypassing the organic material and silts. The degree of mixing between tailings pore water and colluvial water is unknown.

Table 11.—Average constituent concentrations below tailings

Constituent	P3B	P3A	P3C	P3
Conductivity, µS/cm.	3,448	2,456	1,630	1,788
Eh, mV	230	215	181	220
HCO_{1-3}, mg/L	473	674	574	553
pH	6.10	6.40	6.60	6.90
Element, mg/L:				
Al	1.25	0.57	0.33	0.30
B	2.60	0.69	0.56	0.30
Ba	0.04	0.07	0.08	0.09
Ca	536.00	508.00	391.00	363.00
Cu	0.58	0.17	0.09	0.07
Fe	968.00	233.00	197.00	9.20
K	54.30	22.80	12.40	1.90
Mg	610.00	361.00	145.00	127.00
Mn	74.00	22.00	6.50	0.80
Na	65.00	38.00	25.00	38.00
Pb	0.21	0.11	0.10	0.06
S	1,887.00	893.00	504.00	354.00
Si	21.00	16.00	18.00	25.00
Zn	4.50	2.80	0.93	0.35

A third explanation for the low concentrations in the silts below the tailings is that the neutralizing capacity of the calcareous, carbonaceous silt could be inducing precipitation, which would decrease metal concentrations in the silt pore water.

Discussion and Summary of Water Quality Data

The following statements summarize the observed findings regarding the dissolved chemical constituents.

1. The vadose zone is more oxidizing (has higher Eh values) and is more acidic (has lower pH values) than the saturated zone.

2. Several dissolved constituents (sulfur, iron, manganese, lead, zinc, nickel, boron, cadmium, magnesium, and potassium) have higher average concentrations in the saturated tailings than in the vadose tailings. Several possible explanations exist. (a) Some redox species are more soluble under oxidizing conditions, and the oxidation products of easily dissolved minerals have been flushed from the vadose zone, while the presence of remaining sulfides continues to depress the pH; (b) the percentage of fines increases with depth (finer materials tend to have more surface area available for chemical interaction, and may, therefore, cause more dissolved materials to be in solution in the deeper saturated zone); (c) different mineral assemblages may have been mined over time, in which case the corresponding wastes would have depth-dependent changes in properties; or (d) different milling procedures might have been employed at the mill over time, leading to corresponding depth-dependent changes in tailings composition.

The first explanation, offered by Dubrovsky and others (1985), is also supported by the work of Blowes and Jambor (1990). The second explanation, regarding the correlation to grain size, is plausible. Goss and others (1973) demonstrated with radioactively tagged clays that particulate material is transported downward through the vadose zone during infiltration. The third and fourth explanations regarding changes in depth corresponding to changes in depositional history are also possible because of mining (and milling) mineralogically different zones in the ore body, accidental mill reagent (lime, soda ash, crsylic acid, etc.) overdoses, and longer drying-out periods (oxidation exposure) for some portions of the tailings.

3. Concentrations of sodium, calcium, copper, aluminum, and barium tend to be the same for each element throughout both zones. Sodium, calcium, and aluminum are generally not considered redox species; therefore, they would not be influenced differently by the two zones. Phase diagrams for copper and super-sulfate systems indicate that copper is in equilibrium as Cu^{2+} over the range of pH and Eh encountered in both zones. Barium generally has a very low solubility in natural waters.

4. Concentrations of silicon tend to be slightly higher in the vadose zone than in the two saturated zones. Because redox thermodynamics are not likely to control silicon solubility, the higher solubility in the vadose zone is likely to be the result of organic complexing from roots and the influence of wet-dry cycles.

5. Downgradient profiles of average hydrologic and chemical parameters at the field site are shown in figure 12. Groundwater quality dramatically improves in the gravel downgradient of the tailings. Aluminum, copper, iron, lead, silicon, zinc, and pH attenuate rapidly in the first 76 m downgradient from the tailings and reach background levels of 0.3, 0.5, 0.2, 0.03, 15, 0.05 mg/L and 7.0, respectively, at well M5, which lies 550 m from the tailings. Potassium, manganese, magnesium, and sulfate attenuate but do not reach background levels. Downgradient calcium levels remain at the same value as the tailings pore water, and sodium is near background levels in the tailings pore water but increases above background levels downgradient. Also at well M5, pH is up to background levels of 7.0.

6. Two key components, calcium and sulfate, were four times more concentrated downgradient than background. The presence of a significant concentration of sulfate in the tailings coupled with the solubilities of secondary sulfate minerals are major influences on the concentrations of many contaminants. Also, the presence of a significant calcium source in the sediments below the tailings has a major impact on attenuation. Iron is one of the major constituents released during oxidation of sulfide tailings. Downgradient attenuation of iron, as well as other trace metals, such as copper, lead, and zinc, is extremely rapid upon leaving the tailings.

CONCLUSIONS

This report addresses acid production, leaching, transport, and attenuation of dissolved metals at an oxidized, acid-producing tailings impoundment in north-central Washington. This report describes the monitoring, physical properties, and on-site data collection necessary to characterize the site and to determine existing hydrological, physical, and geological conditions. Related reports present multivariate statistical analyses of vadose and saturated pore waters, and hydrological and hydrogeochemical investigations and modeling, (Lambeth, 1992; Williams, 1992). Forty-two monitoring wells were installed upgradient, within, below, and downgradient of the tailings impoundment. During a period of 3 years, pore water samples were taken approximately every 5 weeks and analyzed for dissolved constituents, pH, Eh, conductivity, temperature, DO, and alkalinity. In addition, pore gas samples were collected and water table elevation, tailings temperature, moisture and density, hydraulic conductivity, and groundwater flow velocity measurements were made. Solid samples were collected for mineralogic and chemical analyses and for determination of physical properties.

In the 50 years since deposition of milled tailings ended at the study site, acidic conditions have developed, resulting in high concentrations of dissolved heavy metals and other contaminants in the tailings pore water. Physical observation of the solid samples collected during monitoring well drilling show zones, from top to bottom, of unsaturated tailings, saturated tailings, lake sediments grading into volcanic silts, colluvial gravels, and fractured bedrock. The lake sediments immediately below the tailings consist of 30 to 60 cm of organic-rich material intermixed with silts containing large amounts of snail shells. These below-tailings sediments are instrumental in the geochemical behavior of released tailings pore water. The vadose and saturated zones in the tailings and the saturated lake sediments and silts below the tailings were verified by measured differences in moisture content and density using a downhole neutron probe at eight locations in the tailings pile. Two of the neutron probe profiles showed layers of high moisture in the vadose zone, about 46 cm below the surface. A 61-cm sampling tube pushed through one such layer showed a 2.5- to 5-cm-thick hardpan in the center of the sample. The tailings below the hardpan were much wetter and finer than the tailings above. The hardpan contained high concentrations of iron (from an acid-leaching test) and may reduce the water seepage velocity, alter the direction of flow, and possibly act as an oxidation barrier, slowing the pyrite oxidation process.

Groundwater is in contact with the tailings year around. Piezometric elevations in two multiple-completion wells indicate that groundwater from deeper fractured bedrock upwells into the sediments and possibly the tailings during part of the year. Water from the sediments probably flows into the fractured bedrock during other parts of the year. This water is supplemented by rain and snowmelt that filter through the vadose zone. The low slope of the phreatic surface (5.6×10^{-3}), coupled with the relatively low hydraulic conductivity (10^{-5} cm/s) of the tailings material, results in extremely slow downgradient groundwater flow rates through the tailings and long residence times for mechanical and chemical weathering and reactivity. In addition, grain-size comparisons between vadose and saturated zone samples taken from well P3A showed eight times more 0.01-mm-sized particles in the saturated zone than in the vadose zone. This may be correlated to the large amount of dissolved constituents in the saturated zone because finer materials have more surface area available for chemical reaction.

SEM analysis of the tailings base and sediments below the tailings indicate abundant barium sulfate (barite) in the deep tailings, with detectable amounts of K-feldspar, quartz, and iron oxide. In the organic-rich layer below the tailings, numerous framboidal spheroids composed of iron and sulfur and a mineral assumed to be pyrite were found intermixed with abundant radiolarian debris, alga cysts, and snail shell fragments. The snail shells showed only calcium on the EDS spectrum. Given this type of reducing environment, secondary base-metal sulfides such as chalcocite, covellite, digenite, or sphalerite were expected to exist as coatings on the framboids. However, no secondary base metals were observed with SEM in the organic-rich layer. An EDS spectrum of the silts below the organic-rich layer showed silicon, aluminum, potassium, and calcium, some of the major elements in dacitic-to-rhyolitic glass from volcanic ash falls.

Chemical analyses of the tailings base and sediments below the tailings indicate that solid phase lead and copper are present in the base of the tailings, but not in the organic-rich layer below the tailings, and do not appear to be remobilizing below the tailings. At the base of the tailings, iron is bound primarily to sulfides and oxides, and in the organic-rich layer, iron is bound to oxides, sulfides, carbonates, and organic matter. In the silts below the organic-rich layer, iron and manganese are bound primarily to carbonates. Calcium and magnesium are very abundant in this zone, also in the carbonate form.

Long-term water quality monitoring at the field study site indicates that the vadose zone is more acidic than the saturated zone and appears to have been more aggressively chemically weathered than the saturated zone. Silicate and aluminosilicate dissolution is more advanced in the vadose zone than in the saturated zone. Because the water quality improves dramatically with depth below the tailings, the soluble contaminants in the tailings pore water are not penetrating the base of the tailings into the organic-rich layer and silts below to any great extent, but are probably being transported slowly downgradient through the tailings and are discharged near the southeast end of the tailings pile, where the colluvial gravels are in direct contact with the tailings. After the water leaves the impoundment, several processes aid in downgradient attenuation. These include hydrogeochemical reactions, dilution, advection, and dispersion. At a distance of 550 m downgradient from the impoundment, all measured dissolved constituents naturally attenuate to near-background concentrations except calcium, magnesium, manganese, sodium, and sulfur.

ACKNOWLEDGMENTS

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REFERENCES

Alpers, C. N., and G. H. Brimhall. Paleohydrologic Evolution and Geochemical Dynamics of Cumulative Supergene Metal Enrichment at La Escondida, Atacama Desert, Northern Chile. Econ. Geol., v. 84, 1989, pp. 229-255.

Berner, R. A. Sedimentary Pyrite Formation. Am. J. Sci., v. 268, 1970, pp. 1-23.

Blowes, D. W., J. A. Cherry, and E. J. Reardon. The Hydrogeochemistry of Four Inactive Tailings Impoundments: Perspectives on Tailings Pore Water Evolution. Paper in Proceedings, 1987 National Symposium on Mining, Hydrology, Sedimentology and Reclamation (Univ. KY, Lexington, KY, Dec. 7-11, 1987). Univ, KY, 1987, pp. 253-261.

Blowes, D. W., and J. L. Jambor. The Pore-Water Geochemistry and the Mineralogy of the Vadose Zone of Sulfide Tailings, Waite Amulet, Quebec, Canada. App. Geochem., v. 5, 1990, pp. 327-346.

Boorman, R. S., and D. M. Watson. Chemical Processes in Abandoned Sulphide Tailings Dumps and Environmental Implication for Northeastern New Brunswick. Can. Min. and Metall. Bull., v. 69, 1976, pp. 86-96.

Chanton, J. P., C. S. Martens, and M. B. Goldhaber. Biogeochemical Cycling in an Organic-Rich Coastal Marine Basin. 7. Sulfur Mass Balance, Oxygen Uptake and Sulfide Retention. Geochim. et Cosmochim. Acta, v. 51, 1987, pp. 1187-1199.

Cherry, J. A., R. J. Blackport, N. Dubrovsky, R. W. Gillham, T. P. Lim, D. Murray, E. J. Reardon, and D. J. A. Smyth. Subsurface Hydrology and Geochemical Evolution of Inactive Pyrite Tailings in the Elliot Lake Uranium District, Canada. Paper in Uranium Mill Tailings Management: Proceedings of the Third Symposium (CO State Univ., Ft. Collins, CO, Nov. 24-25, 1980). Civil Eng. Dept., CO State Univ., 1980, pp. 353-385.

Cherry, J. A., F. M. M. Morel, J. V. Rouse, J. L. Schnoor, and M. G. Wolman. Hydrogeochemistry of Sulfide and Arsenic-Rich Tailings and Alluvium Along Whitewood Creek, South Dakota. Miner. and Energy Res., v. 29, No. 4, 1986, pp. 1-12; No. 5, pp. 1-16; No. 6, pp. 1-16.

Drees, L. R., L. P. Wilding, N. E. Smeck, and A. L. Senkayi. Silica in Soils: Quartz and Disordered Silica Polymorphs. Ch. 19 in Minerals in Soil Environments, ed. by J. B. Dixon and S. B. Weed. Soil Sci. Soc. Am., Book Series 1, 2nd ed., 1989, pp. 913-974.

Dubrovsky, N. M., J. A. Cherry, E. J. Reardon, and A. J. Vivyurka. Geochemical Evolution of Inactive Pyritic Tailings in the Elliot Lake Uranium District. Can. Geotech., v. 22, 1985, pp. 110-128.

Goldhaber, M. B., and I. R. Kaplan. Controls and Consequences of Sulfate Reduction Rates in Recent Marine Sediments. Ch. 2 in Acid Sulfate Weathering, ed. by J. A. Kittrick, D. S. Fanning, and L. R. Hossner. Spec. Publ. 10, Soil Sci. Soc. Am., 1982, pp. 19-36.

Goss, D. W., S. J. Smith, B. A. Stewart, and R. O. Jones. Fate of Suspended Sediment During Basin Recharge. Water Resour. Res., v. 9, 1973, pp. 668-675.

Hem, J. D. Geochemical Controls on Lead Concentrations in Stream Water and Sediments. Geochim. et Cosmochim. Acta, v. 40, 1976, pp. 599-609.

___. Study and Interpretation of Chemical Characteristics of Natural Water. U.S. Geol. Surv. Water-Supply Paper 2254, 3rd ed., 1985, 263 pp.

Klein, C., and C. S. Hurlbut, Jr. Manual of Mineralogy (after J. D. Dana). John Wiley & Sons, 20th ed., 1985, pp. 428-429.

Lambeth, R. H. Hydrogeochemical Characteristics of an Unconsolidated Aquifer Downgradient from an Oxidized, Sulfidic Mine Tailings Impoundment. M.S. Thesis, E. WA Univ., Cheney, WA, 1992, 140 pp.

Mok, W. M., and C. M. Wai. Simultaneous Extraction of Trivalent and Pentavalent Antimony and Arsenic Species in Natural Waters for Neutron Activation Analysis. Analyt. Chem., v. 59, 1987, pp. 233-236.

Nordstrom, D. K. Aqueous Pyrite Oxidation and the Consequent Formation of Secondary Iron Minerals. Ch. 3 in Acid Sulfate Weathering, ed. by J. A. Kittrick, D. S. Fanning, and L. R. Hossner. Spec. Publ. 10, Soil Sci. Soc. Am., 1982, pp. 37-56.

Nordstrom, D. K., and J. W. Ball. The Geochemical Behavior of Aluminum in Acidified Surface Waters. Science, v. 232, 1986, pp. 54-56.

Petsonk, A. M. BAT Groundwater Monitoring System Piezometer Installation Guide. BAT Envitech, Inc., Long Beach, CA, 1985, 20 pp.

___. The BAT Method of In Situ Measurement of Hydraulic Conductivity in Saturated Soils. Thesis in Hydrogeology, Uppsala Univ., Uppsala, Sweden, 1984, 54 pp.

Stewart, B. M., R. H. Lambeth, and B. C. Williams. Effects of Pyritic Tailings in an Abandoned Impoundment on Downgradient Ground Water Quality. Ch. 16 in Mining and Mineral Processing Wastes: Proceedings of the Western Regional Symposium on Mining and Mineral Processing Wastes, ed. by F. M. Doyle (Berkeley, CA, May 30-June 1, 1990). SME, Littleton, CO, 1990, pp. 133-142.

Taylor, B. E., M. C. Wheeler, and D. K. Nordstrom. Stable Isotope Geochemistry of Acid Mine Drainage: Experimental Oxidation of Pyrite. Geochim. et Cosmochim. Acta, v. 48, 1984, pp. 2669-2678.

Taylor, J. K. Statistical Techniques for Data Analysis. Lewis Publ., Chelsea, MI, 1990, pp. 87-92, 169.

U.S. Bureau of Reclamation (Denver, CO). Unified Soil Classification System. 1963, 26 pp.

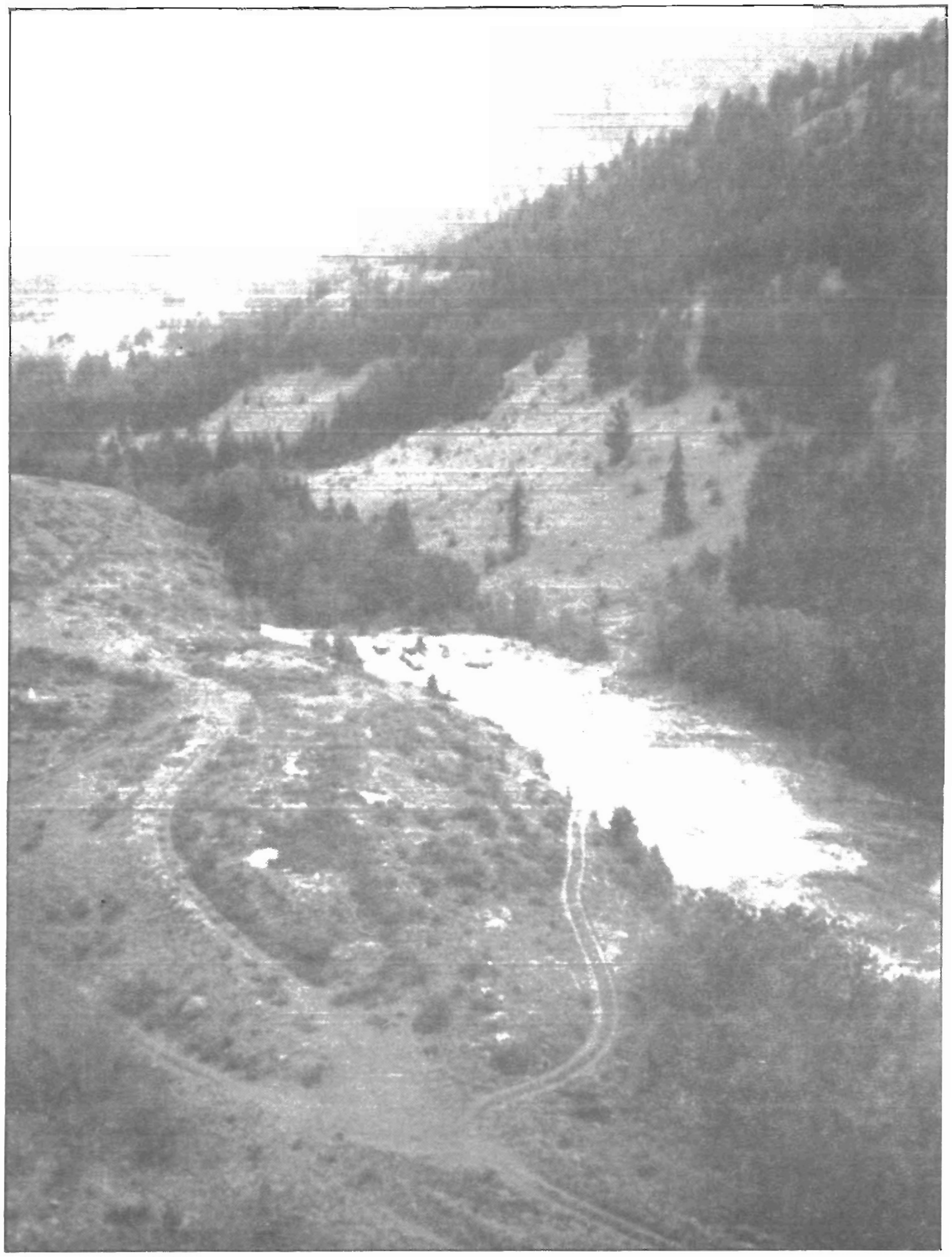
U.S. Environmental Protection Agency. National Oil and Hazardous Substance Pollution Contingency Plan. Proposed rule. 53 Federal Register 51394, 1988.

Washington State Department of Ecology. Water Well Construction Act of 1971, Minimum Standards for Construction and Maintenance of Wells. WAC ch. 173-160. Reprinted May 1988, 61 pp.

Williams, B. C. Multivariate Statistical Analysis of Vadose and Saturated Zone Pore Waters of Sulfidic Mine Waste Tailings. Ch. 10 in Emerging Process Technologies for a Cleaner Environment, ed. by S. Chander. Soc. Min. Eng., 1992, pp. 63-70.

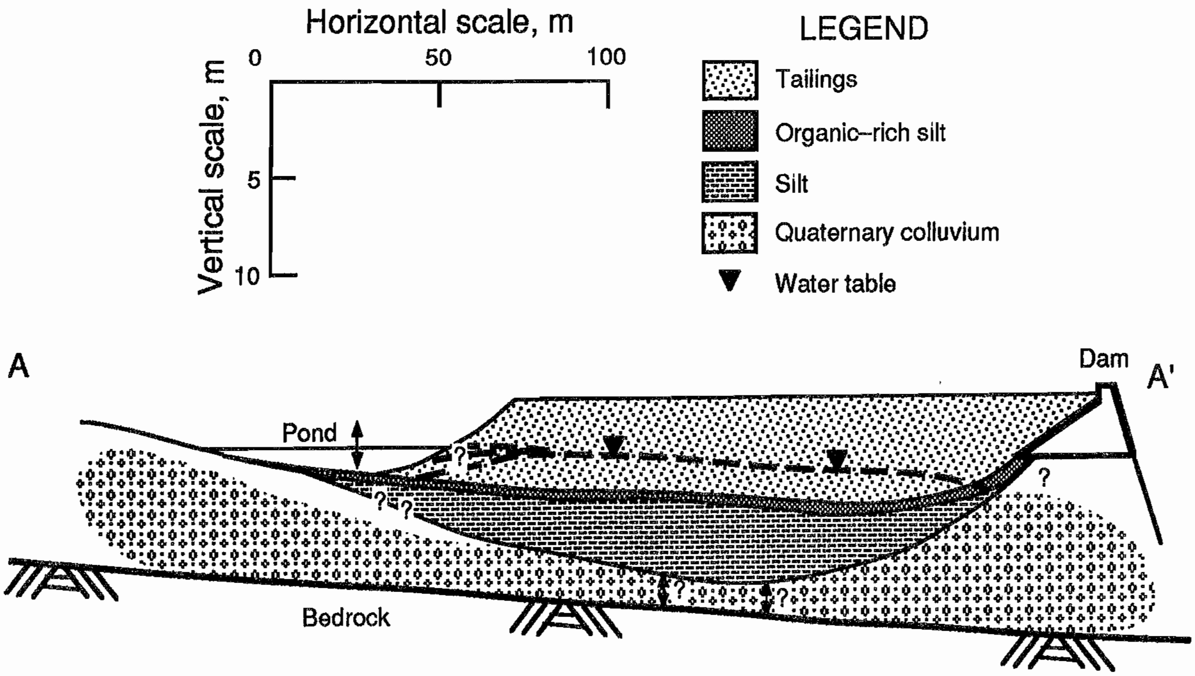
Wood, B. D., C. K. Keller, and D. L. Johnstone. In Situ Measurement of Microbial Activity and Controls on Microbial CO_2 Production in the Unsaturated Zone. Water Resour. Res., v. 29, No. 3, 1993, pp. 647-559.

Figure 1



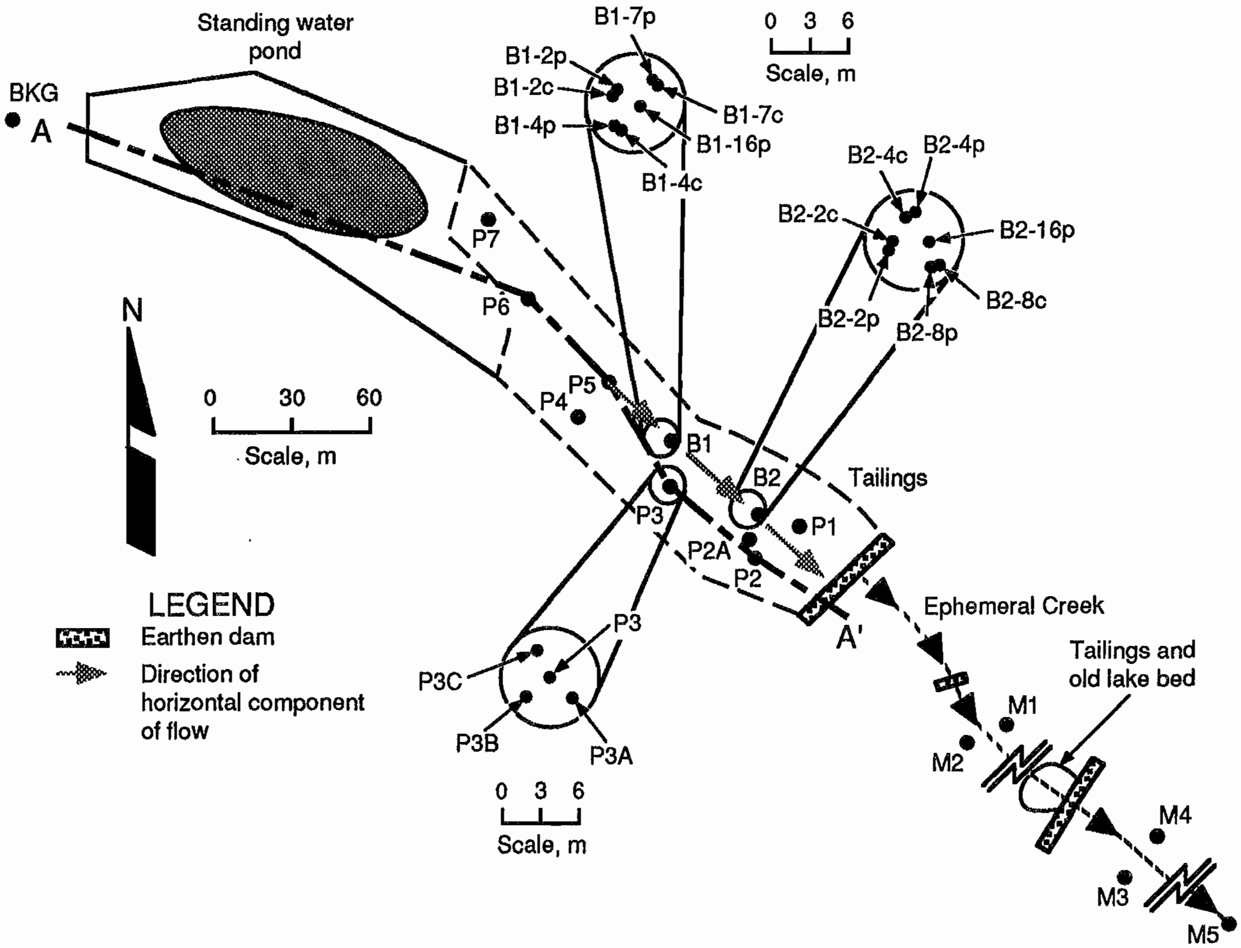
Low-angle photograph of study site looking downgradient.

Figure 2



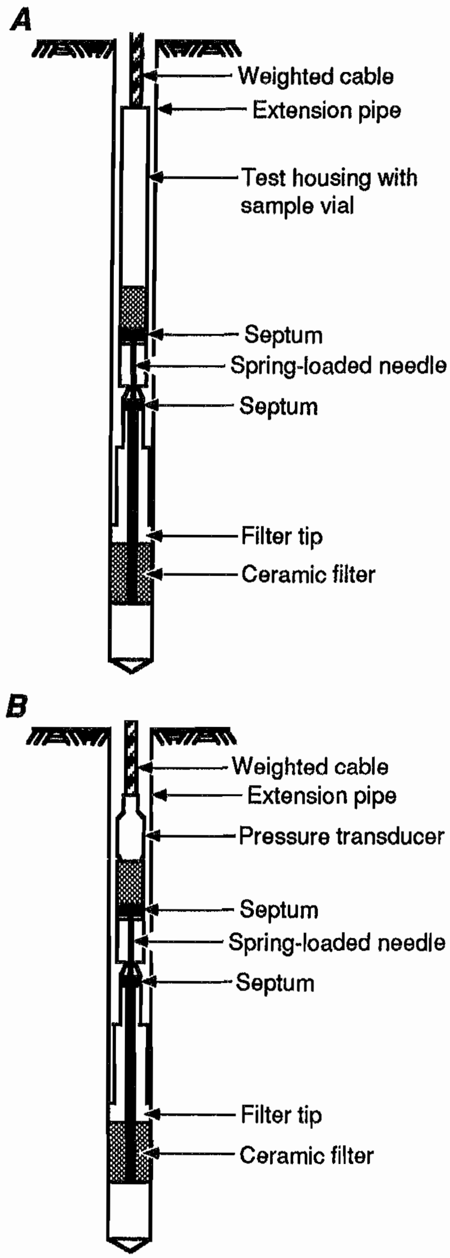
Cross section of tailings impoundment and stratigraphy below impoundment.

Figure 3



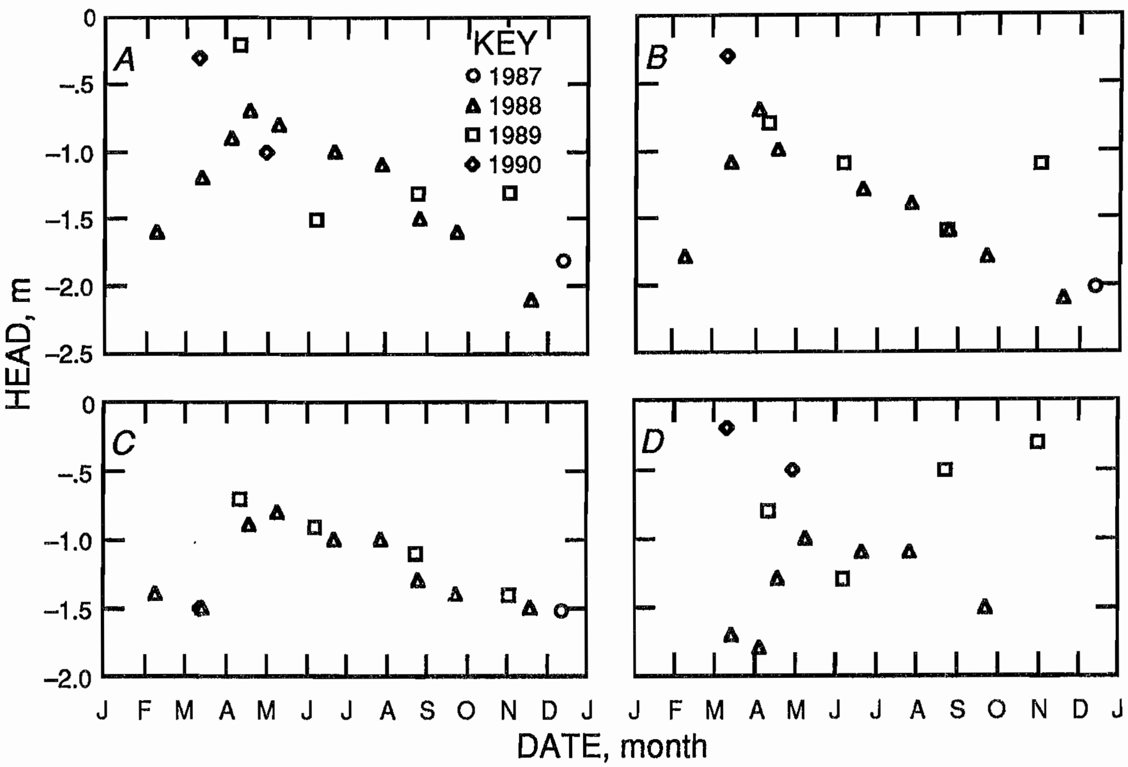
Plan view of research site and monitoring well locations.

Figure 4



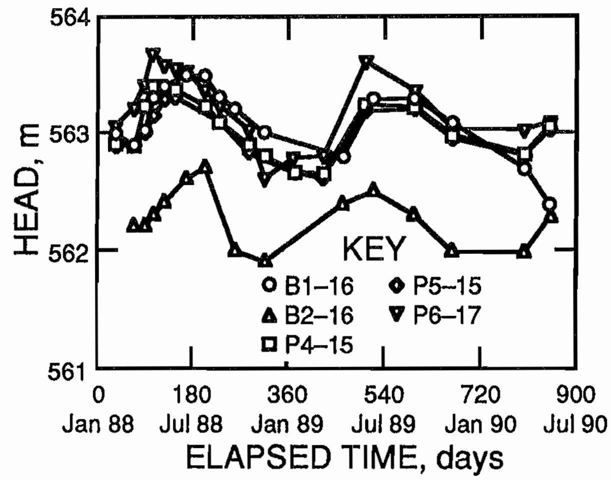
Cross section of BAT sampler. A, Sample vial; B, pressure transducer.

Figure 5



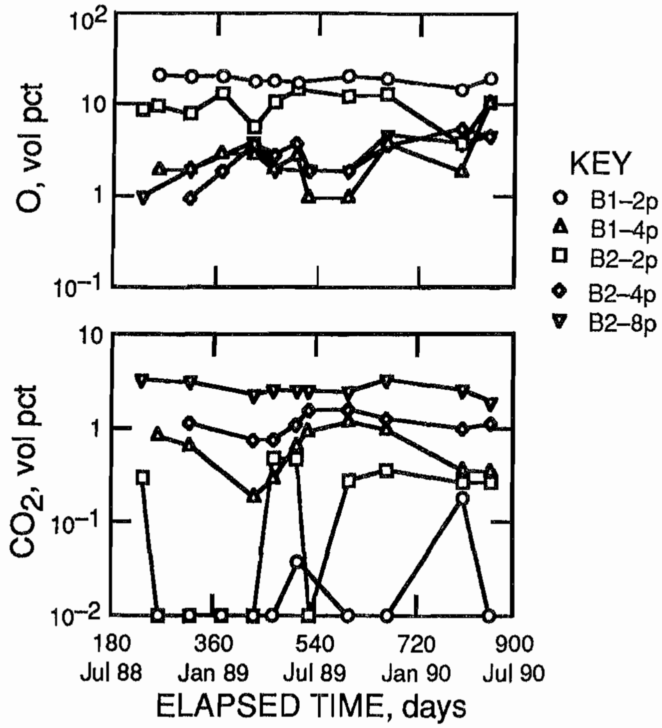
Gauge pressure data from vadose zone. A, B1-4c; B, B2-4c; C, B1-7c, D, B2-8c.

Figure 6



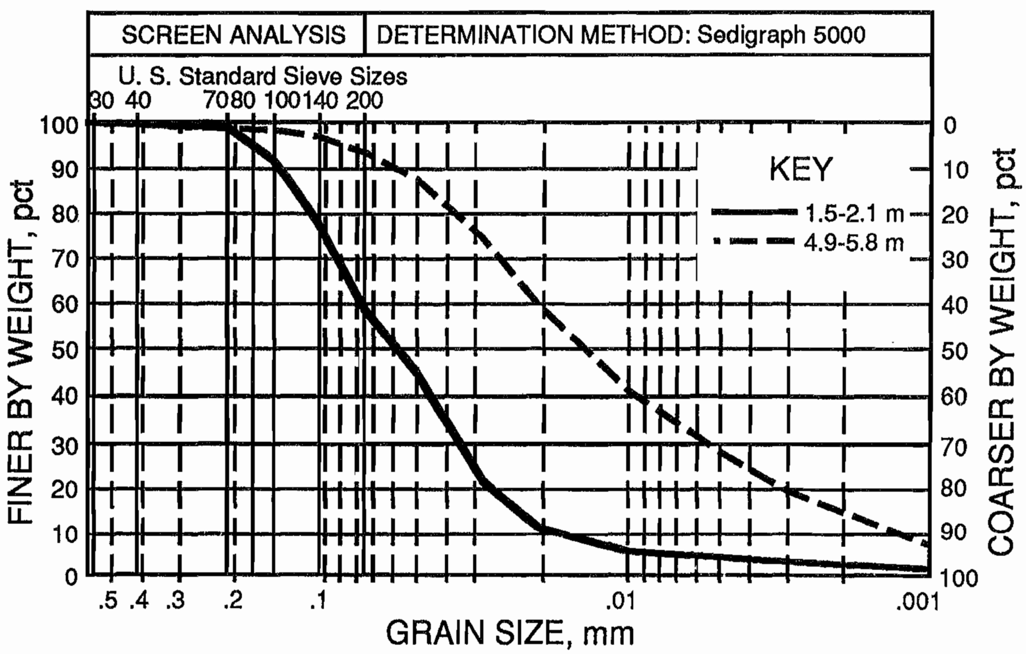
Head data from saturated zone sampling locations plotted against time.

Figure 7



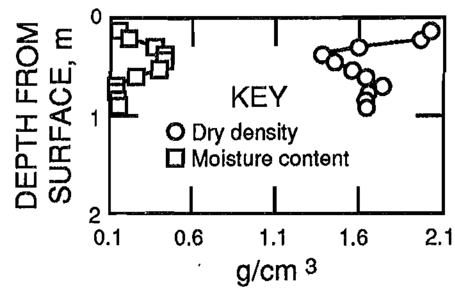
Oxygen and carbon dioxide content at vadose zone sampling locations plotted against time.

Figure 8



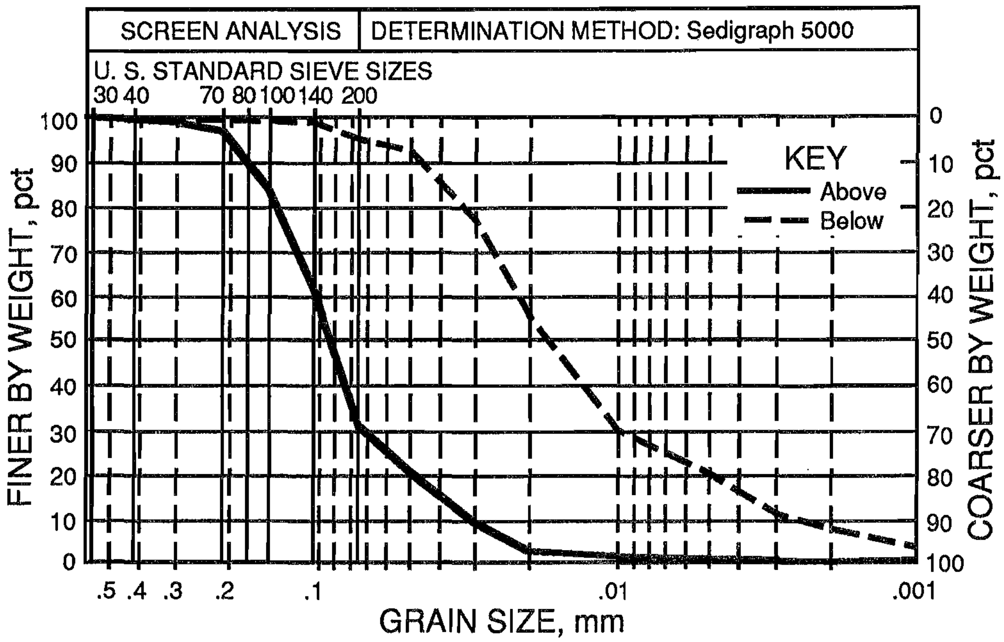
Grain-size distribution of samples from vadose zone (solid line) and saturated zone (dotted line), well P3A.

Figure 9



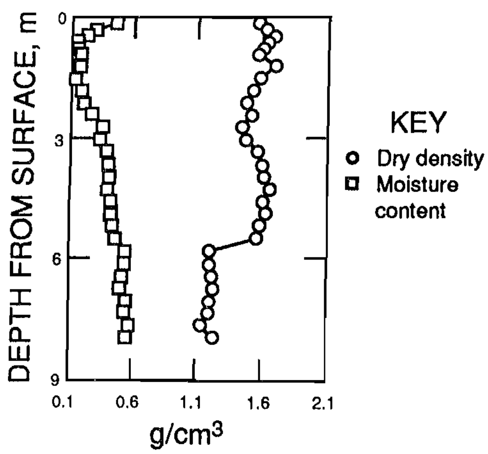
Moisture and density profiles in vadose zone, well B2-4c.

Figure 10



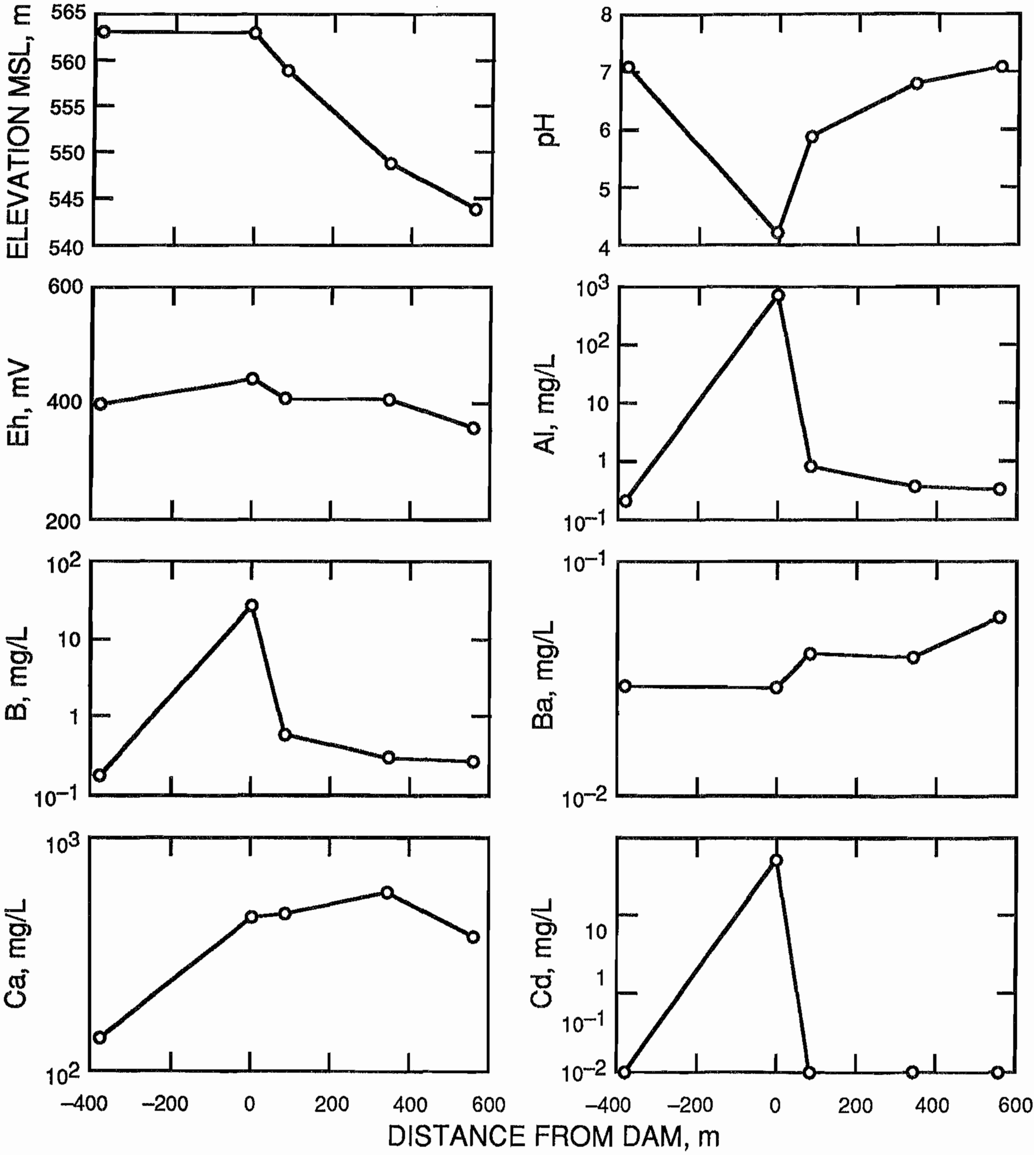
Grain-size distribution in samples above and below hardpan. The samples were collected in a zone extending from the surface to a depth of 76 cm near well B2-2c.

Figure 11



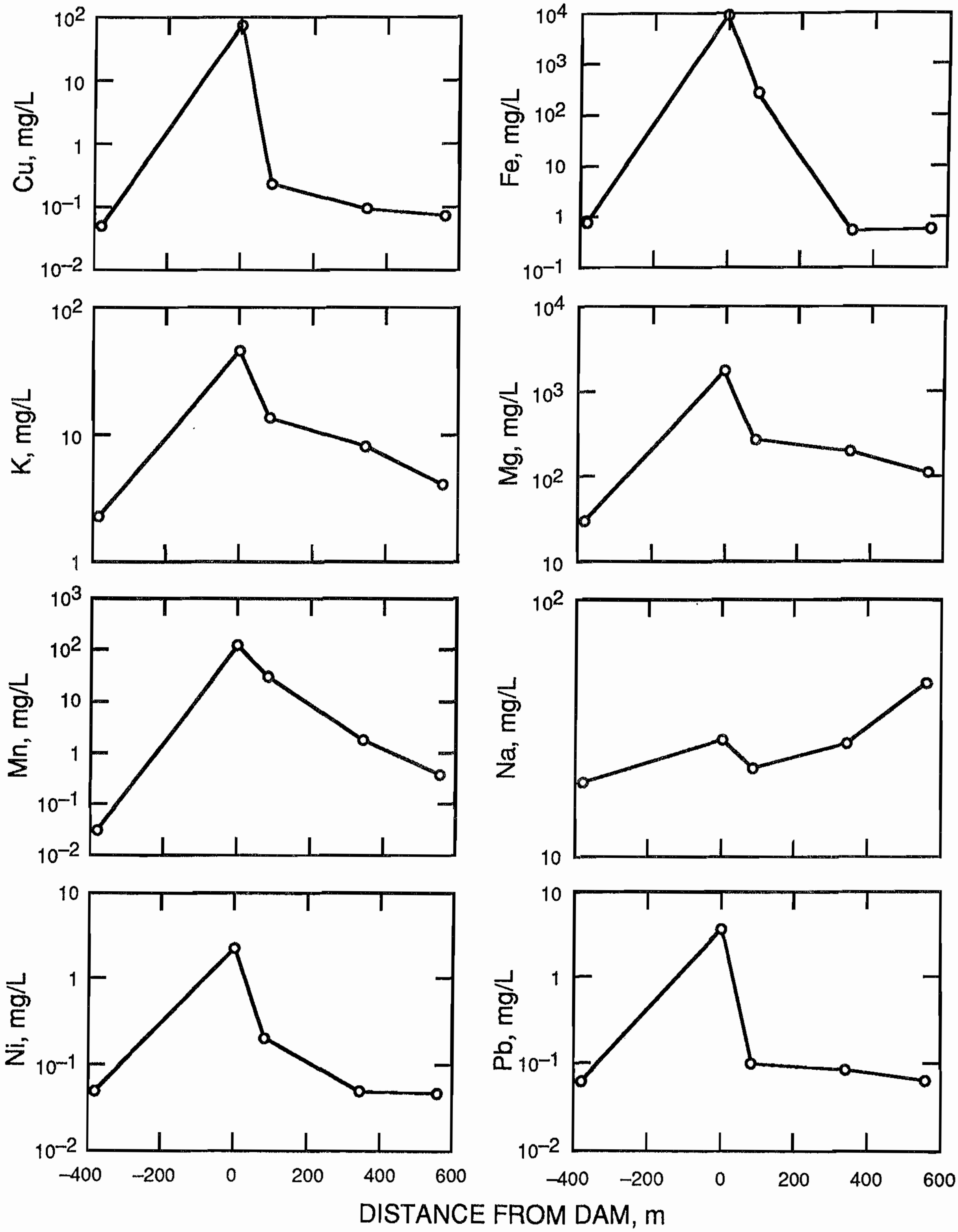
Moisture and density profiles in tailings and silts below tailings near well P3. Changes between the two units are noticeable at 5.8 m.

Figure 12



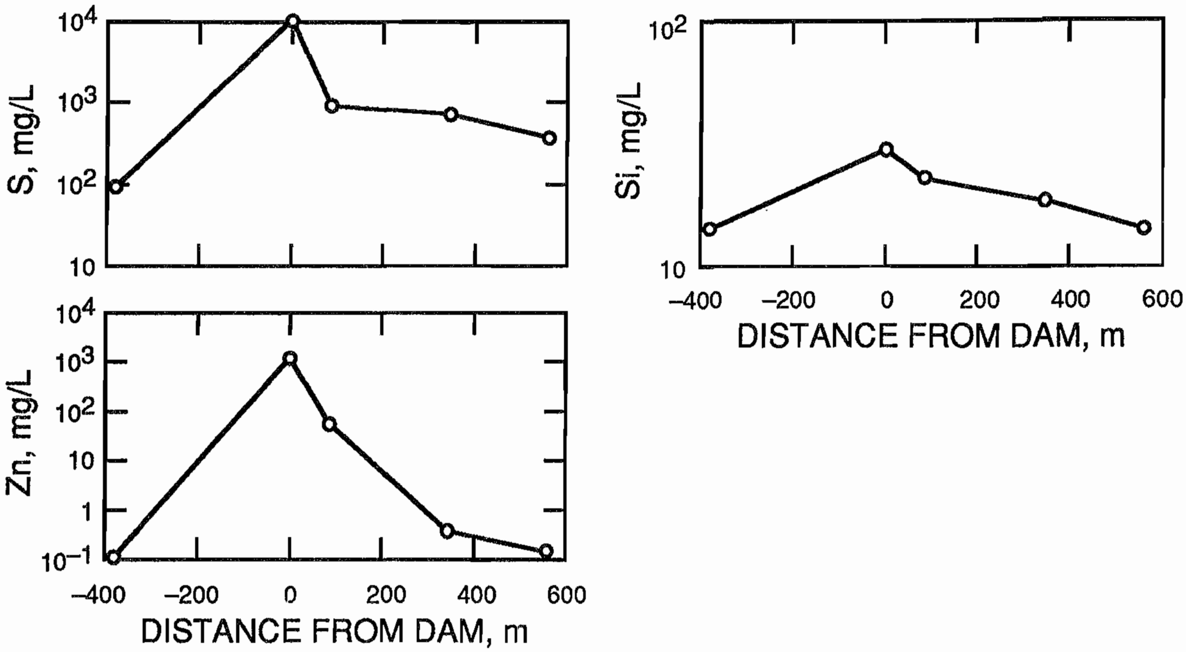
Changes in elevation, pH, Eh, and metal concentrations in shallow groundwater from background (-400 m), through the tailings (0 m), to three locations downgradient (76, 335, and 550 m).

Figure 12—Continued



Changes in elevation, pH, Eh, and metal concentrations in shallow groundwater from background (-400 m), through the tailings (0 m), to three locations downgradient (76, 335, and 550 m).

Figure 12—Continued



Changes in elevation, pH, Eh, and metal concentrations in shallow groundwater from background (-400 m), through the tailings (0 m), to three locations downgradient (76, 335, and 550 m).

APPENDIX A.—WELL COMPLETION REPORTS FOR P, M, AND BKG WELLS

RESOURCE PROTECTION WELL REPORT

START CARD NO. ____

PROJECT NAME: Hydrogeologic Phenomena - Mine Waste Management

COUNTY: Okanogan

WELL IDENTIFICATION NO. P1

LOCATION: SE 1/4 SE 1/4 Sec 18 Twn 33N R 22E

DRILLING METHOD: Hollow Stem Auger

STREET ADDRESS OF WELL: ____

DRILLER: ____

FIRM: U.S.B.M.

WATER LEVEL ELEVATION: ____

SIGNATURE: ____

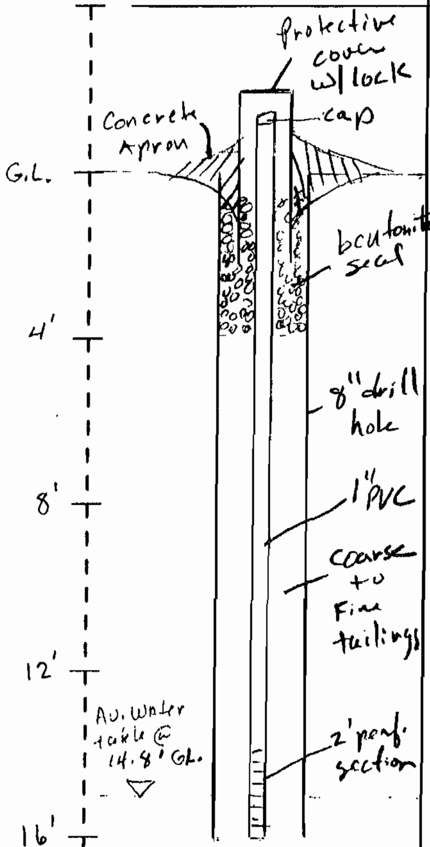
GROUND SURFACE ELEVATION: 1859.8' Above Sea level.

CONSULTING FIRM: ____

INSTALLED: 10/1/87

REPRESENTATIVE: ____

DEVELOPED: ____

AS-BUILT	WELL DATA	FORMATION DESCRIPTION
	Naturally ~~developed~~ completed well in which the formation was allowed to collapse around the ~~Perforated section~~ casing. Well casing is 1" PVC with a 2' slotted section (factory slots). Well was developed by over pumping until water became clarified. Dedicated 3/8" tubing was installed in the well for sampling with peristaltic pump. Bottom of casing is at about 16' from Ground level.	0 - 2'3" Light Brown Sandy tailings 2'3" - 3' Grey to Blue very fine sand layer 3' - 14'10" Grey Coarse Sandy tailings 14'10" - 15'6" Calcareous, Carbonaceous Silt Layer 15'6" - 16' Gravel/Grey Sand mix

SCALE: 1" = 4'

PAGE 1 OF 1

ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

START CARD NO. ____________

PROJECT NAME: Hydrogeologic Phenomena - Mine Waste Management

WELL IDENTIFICATION NO. P2

DRILLING METHOD: Hollow Stem Auger

DRILLER: ____________

FIRM: U.S.BM

SIGNATURE: ____________

CONSULTING FIRM: ____________

REPRESENTATIVE: ____________

COUNTY: Okanogan

LOCATION: SE 1/4 SE 1/4 Sec 18 Twn 33N R 22E

STREET ADDRESS OF WELL: ____________

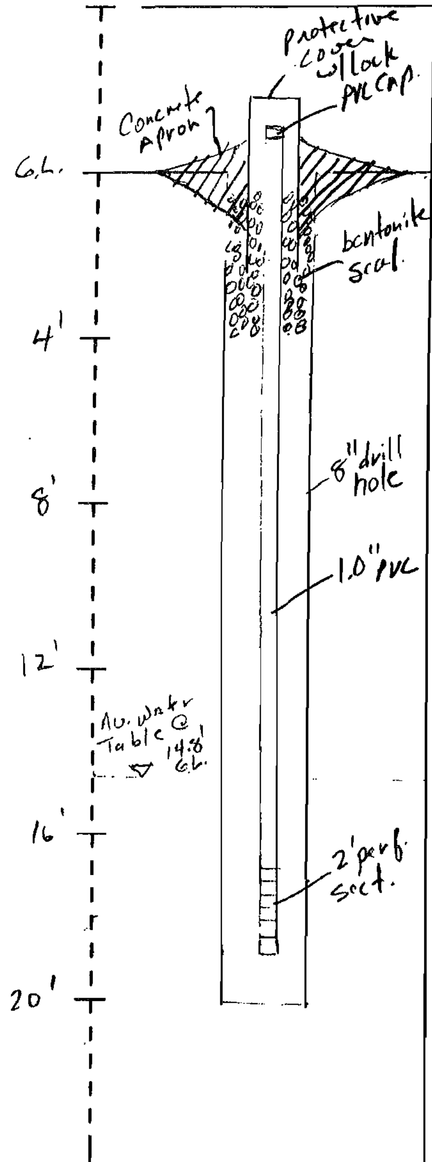
WATER LEVEL ELEVATION: ____________

GROUND SURFACE ELEVATION: 1859.2 Above Sea level

INSTALLED: 10/2/87

DEVELOPED: ____________

AS-BUILT



WELL DATA

Naturally completed well in which the formation was allowed to collapse around the casing as the augers were being removed. Sections when hole stayed open above the water level were backfilled with augured material.

Well casing is 1" pvc with a 2' slotted section (0.01" factory slots)

Well was developed by over pumping until water became clarified.

dedicated 3/8" tubing was installed for sampling with peristaltic pump

FORMATION DESCRIPTION

0-5' medium grey to Brown Sandy tailings w/ a 3" Grey/Blue fine sand layer in middle.

5'-10'6" Consistent light Brown medium to Coarse Sandy tailings w/ 5" wet layer in middle.

10'6"-14'9" Saturated dark Brown tailings.

14'9"-15'9" Black Calcareous/ Carbonaceous fine sand to silt layer

15'9"-19' gravel & grey sand mix

19'-20' Coarse gravel.

SCALE: 1" = 4'

PAGE ________ OF ________

ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

START CARD NO. ______

PROJECT NAME: Hydrogeologic Phenomena - Mine Waste Management

WELL IDENTIFICATION NO. P3

DRILLING METHOD: Hollow Stem Auger

DRILLER: ______

FIRM: U.S.B.M.

SIGNATURE: ______

CONSULTING FIRM: ______

REPRESENTATIVE: ______

COUNTY: Okanogan

LOCATION: SE 1/4 SE 1/4 Sec 18 Twn 33N R 22E

STREET ADDRESS OF WELL: ______

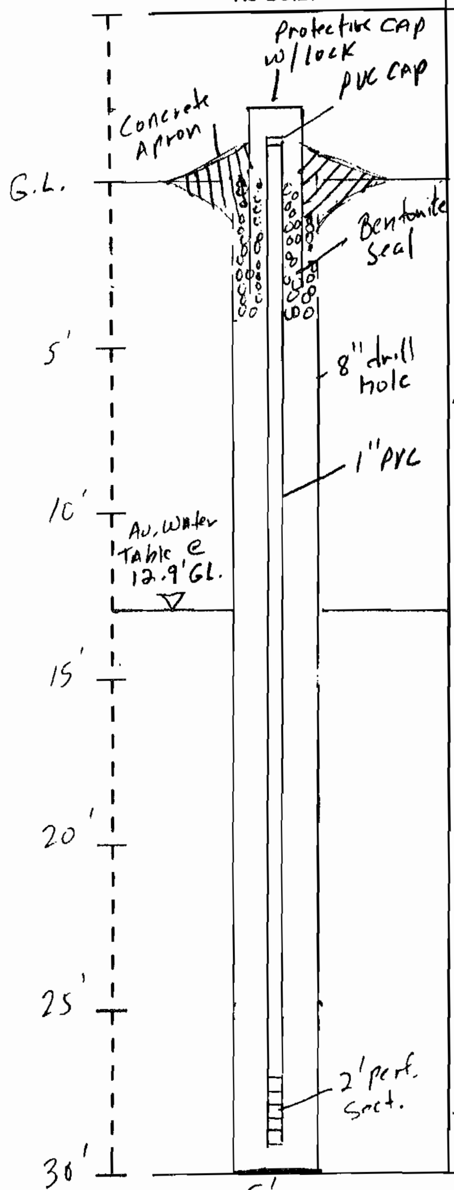
WATER LEVEL ELEVATION: ______

GROUND SURFACE ELEVATION: 1858.4' Above S.L.

INSTALLED: 10/6/87

DEVELOPED: ______

AS-BUILT



WELL DATA

Naturally completed well in which the formation was allowed to collapse around the casing as the augers were being removed. Sections where hole stayed open above the water level were backfilled with augered material.

Well casing is 1" PVC with a 2' slotted section (.01" factory slots)

Well was developed by overpumping until water became clarified.

Dedicated 3/8" tubing was installed in the well for sampling with peristaltic pump.

FORMATION DESCRIPTION

0-3' - oxidized rust colored tailings with 2" white layer in center.

3-5' - took Shelby tube sample (No description)

5'-8' - reddish/Gray tailings

8'-10' - took Shelby tube sample (No description)

10'-15' - Grey liquidy tailings

15'-20' - Grey to Brown liquidy tailings. last 1" calcareous carbonaceous silt

20'-20½' - Calcareous/carbonaceous silt layer

20½'-25' - Mix of grey silt and carbonaceous silt with shells + roots

25'-30' Same as last with bottom 2' containing gravel. HS ~~order~~. Odor.

SCALE: 1" = 5'

PAGE ______ OF ______

ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

PROJECT NAME: Hydrogeologic Phenomena - Mine Waste Management

WELL IDENTIFICATION NO. P3A

DRILLING METHOD: Hollow Stem Auger

DRILLER:

FIRM: U.S.B.M

SIGNATURE:

CONSULTING FIRM:

REPRESENTATIVE:

START CARD NO.

COUNTY: Okanogan

LOCATION: SE ¼ SE ¼ Sec 18 Twn 33N R 22E

STREET ADDRESS OF WELL:

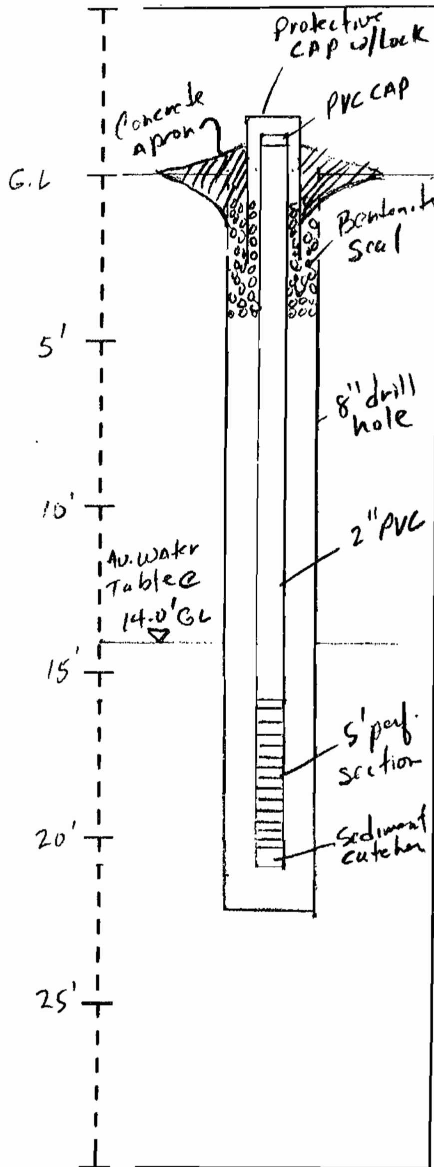
WATER LEVEL ELEVATION:

GROUND SURFACE ELEVATION: No elev. taken.

INSTALLED: 5/1/90

DEVELOPED:

AS-BUILT



WELL DATA

naturally completed well in which the formation was allowed to collapse around the casing as augers were being removed. Sections when hole stayed open above the water level were backfilled with augered material.

Well casing is 2" pvc with 5' slotted section (0.02" factory slots) + + 6" sediment catcher.

well was developed by overpumping until water became clarified.

Dedicated 3/8" tubing was installed for sampling with peristaltic pump.

FORMATION DESCRIPTION

0-5' oxidized tailings with 2" quartz in middle. Last 4" grey coloured tailings.

5'-8' Course to fine tailings

8'-10' shelby tube (No description)

10'-13' grey, slimey tailings.

13'-16' brown to grey slimey tailings (brown + gray lenses)

16'-18'9" brown slimey tailings w/ a reddish oxidized ? zone (3").

18'9"-20'2" calcareous/carbonaceous (organic) layer (NO gravel)

20'2"-22' - carbonaceous shales to grey/brown silty clay.

SCALE: 1" = 5'   PAGE 1 OF 1

ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

START CARD NO. ________

PROJECT NAME: Hydrogeologic Phenomena - Mine Waste Management

WELL IDENTIFICATION NO. P3B

DRILLING METHOD: Hollow Stem Auger

DRILLER:

FIRM: U.S.B.M.

SIGNATURE:

CONSULTING FIRM:

REPRESENTATIVE:

COUNTY: Okanogan

LOCATION: SE 1/4 SE 1/4 Sec 18 Twn 33N R 22E

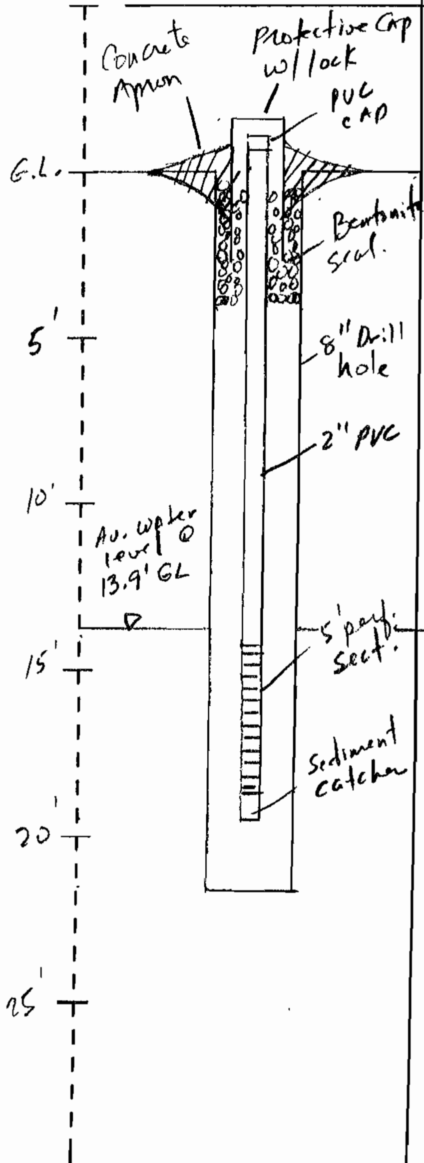
STREET ADDRESS OF WELL:

WATER LEVEL ELEVATION:

GROUND SURFACE ELEVATION: No. elev. taken

INSTALLED: 5/1/90

DEVELOPED:

AS-BUILT	WELL DATA	FORMATION DESCRIPTION
	SAme as P3A	No formation description for this hole. Did not take split spoon or Shelby tube samples.

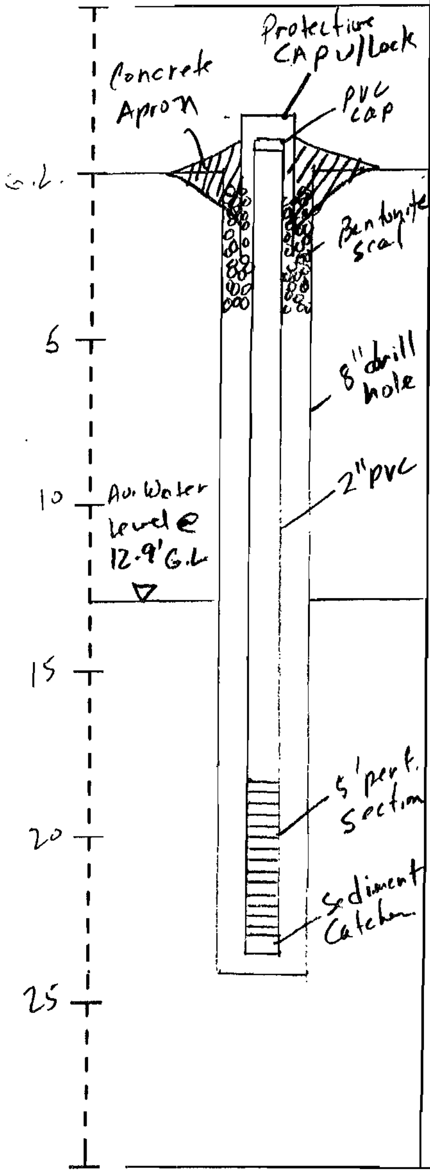
SCALE: 1" = 5'

PAGE ________ OF ________

ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

PROJECT NAME: Hydrogeologic Phenomena - Mine Waste Management	START CARD NO.
WELL IDENTIFICATION NO. P3C	COUNTY: Okanogan
DRILLING METHOD: Hollow Stem Auger	LOCATION: SE 1/4 SE 1/4 Sec 18 Twn 33N R 22E
DRILLER:	STREET ADDRESS OF WELL:
FIRM: U.S.B.M.	WATER LEVEL ELEVATION:
SIGNATURE:	GROUND SURFACE ELEVATION:
CONSULTING FIRM:	INSTALLED: 5/1/90
REPRESENTATIVE:	DEVELOPED:

AS-BUILT	WELL DATA	FORMATION DESCRIPTION
	Same As P3A	0-15' no description 15'-18' grey/brown to reddish/brown slimey tailings. 18'-19' oxidized slimey tailings. 19'-19 1/2' Carbonaceous layers 19 1/2'-21' Carbonaceous shale to grey silt 21'-23' alternating silt & carbonaceous (org.) layers (6") 23'-24' grey silt.

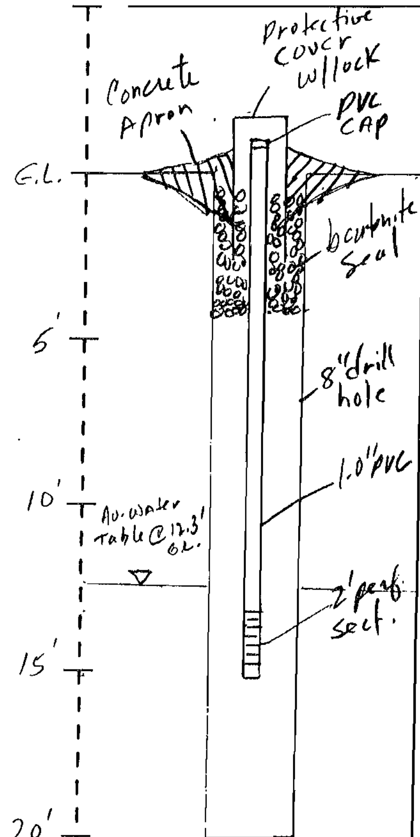
SCALE: 1" = PAGE OF

ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

PROJECT NAME: Hydrogeologic Phenomena - Mine Waste Management
WELL IDENTIFICATION NO. P4
DRILLING METHOD: Hollow STEM Auger
DRILLER:
FIRM: U.S.BM.
SIGNATURE:
CONSULTING FIRM:
REPRESENTATIVE:

START CARD NO.
COUNTY: Okanogan
LOCATION: SE 1/4 SE 1/4 Sec 18 Twn 33N R 22E
STREET ADDRESS OF WELL:
WATER LEVEL ELEVATION:
GROUND SURFACE ELEVATION: 1857.3' above Sea level
INSTALLED: 10/6/87
DEVELOPED:

AS-BUILT	WELL DATA	FORMATION DESCRIPTION
	Naturally Completed well in which the formation was allowed to collapse around the casing as augers were being removed, Sections where hole stayed Open above the water level were backfilled with augered material. Well casing is 1" pvc with 2' Slotted section (0.01" factory slots) well was developed by overpumping until water became clarified. Dedicated 3/8" tubing was installed for sampling with peristaltic pump.	0-5' Iron stained brown Sandy tailings with 6" white (qtz?) layer in middle. 5'-10' SAme as last with bottom 1' gray colored & wet (No Iron stain) 10'-15' grey/brown course tailings (no fines or slimes) 15'-18 1/2' grey/brown sat "quick" tails. 18'-19' Carbonaceous/Calcareous lake Sediments.

SCALE: 1" = 5'   PAGE ____ OF ____

ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

START CARD NO. ______

PROJECT NAME: Hydrogeologic Phenomena – Mine Waste Management

WELL IDENTIFICATION NO. P5

DRILLING METHOD: Hollow Stem Auger

DRILLER: ______

FIRM: U.S.B.M

SIGNATURE: ______

CONSULTING FIRM: ______

REPRESENTATIVE: ______

COUNTY: Okanogan

LOCATION: SE 1/4 SE 1/4 Sec 18 Twn 37N R 22E

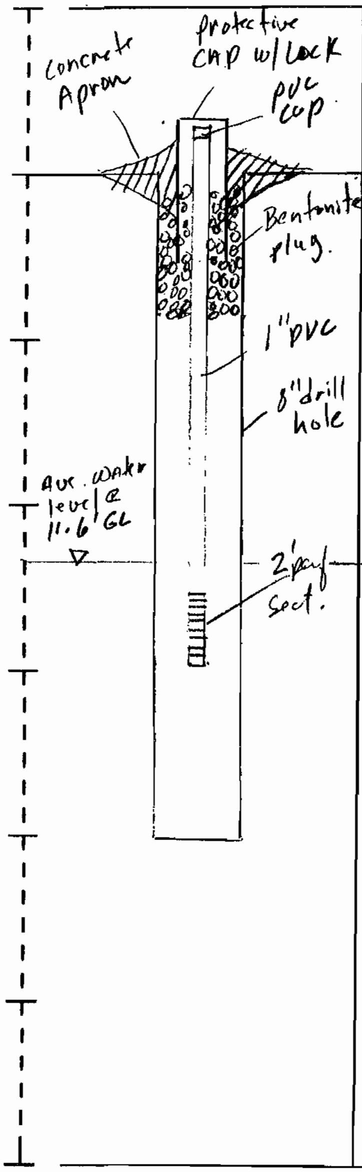
STREET ADDRESS OF WELL: ______

WATER LEVEL ELEVATION: ______

GROUND SURFACE ELEVATION: 1858.6' Above Sea level

INSTALLED: 10/7/87

DEVELOPED: ______

AS-BUILT	WELL DATA	FORMATION DESCRIPTION
	Naturally completed well in which the formation was allowed to collapse around the casing as augers were being removed. Sections where hole stayed open above the water level were backfilled with augered material. Well casing is 1" pvc with 2' slotted section (0.01" factory slots) Well was developed by overpumping until water became clarified. Dedicated 3/8" tubing was installed for sampling with peristaltic pump.	0-5' Iron stained, buff colored medium fine sandy tailings with 6" white sand layer in middle. 5'-7' Iron stained medium sandy tailings 7'-7½' brown/buff colored "mud" 7½'-15' med grey colored sandy tailings with buff tint. last 1' finer & browner. 15'-18½' med grey to brown sandy tailings 18½'-19' fine brown silty tailings 19'-20' Carbonaceous/Calcareous (shelly) like sediment.

SCALE: 1" = ______

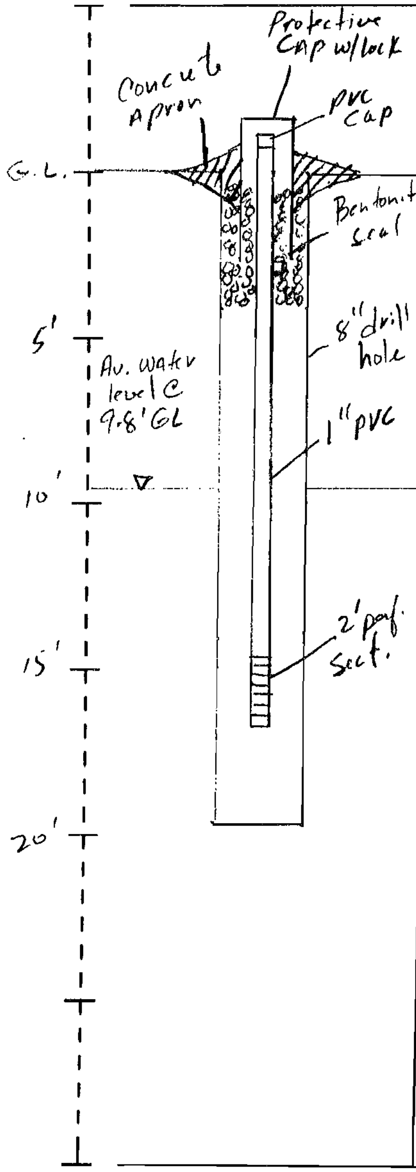
PAGE 1 OF 1

ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

PROJECT NAME: Hydrogeologic Phenomena – Mine Waste Management	START CARD NO.
WELL IDENTIFICATION NO. P6	COUNTY: Okanogan
DRILLING METHOD: Hollow Stem Auger	LOCATION: SE 1/4 SE 1/4 Sec 18 Twn 33N R 22E
DRILLER:	STREET ADDRESS OF WELL:
FIRM: U.S.B.M.	WATER LEVEL ELEVATION:
SIGNATURE:	GROUND SURFACE ELEVATION: 1857.4' abv S.L.
CONSULTING FIRM:	INSTALLED: 10/7/87
REPRESENTATIVE:	DEVELOPED:

AS-BUILT



WELL DATA

Naturally completed well in which the formation was allowed to collapse around the casing as augers were being removed. Sections where hole stayed open above the water level were backfilled w/ augered material

Well casing is 1" pvc with 2' slotted section (0.01" factory slots)

Well was developed by over pumping until water became clarified

Dedicated 3/8" tubing was installed for sampling w/ peristaltic pump.

FORMATION DESCRIPTION

0 - 2 1/2' powdery buff colored tailings.

2 1/2' - 4 1/2' loss Fe-stain

4 1/2' - 5' loss Fe-stain w/ trace of black colored material.

5' - 6' Med sandy tails w/ Fe-stain

6' - 10 1/2' Fine grey slime tailings w/ no Fe-stain.

10 1/2 - 17 1/2 grey slime tailings

17 1/2 - 19' - grey/brown slime tailings.

19' - 19 1/2' lake sediments

SCALE: 1" =

PAGE ____ OF ____

ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

START CARD NO. ______

PROJECT NAME: Hydrogeologic Phenomena - Mine Waste Management

COUNTY: OKanogan

WELL IDENTIFICATION NO. M1 (7, 11, 28)

LOCATION: NE 1/4 NE 1/4 Sec 19 Twn 33N R 22E

DRILLING METHOD: air Rotary w/ Down hole hammer

STREET ADDRESS OF WELL: ______

DRILLER: ______

FIRM: U.S.D.M.

WATER LEVEL ELEVATION: ______

SIGNATURE: ______

GROUND SURFACE ELEVATION: ______

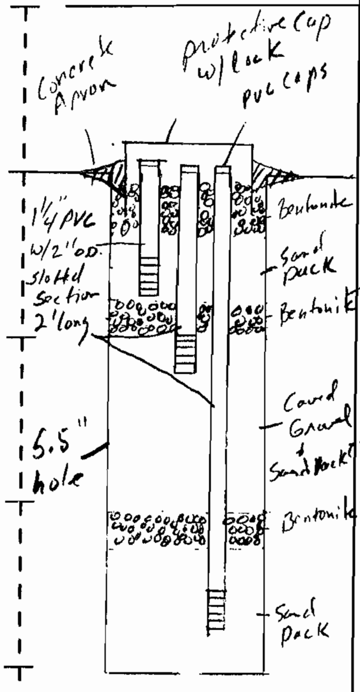
CONSULTING FIRM: ______

INSTALLED: 7/1/87

REPRESENTATIVE: ______

DEVELOPED: ______

AS-BUILT



Ao. WAter level

40' M1-7 ≅ ~~5.6~~ 4.5' GL

M1-11 ≅ ~~6.53~~ 5.4' GL

M1-28 ≅ ~~6.50~~ 5.4' GL

WELL DATA

This is a multiple completed well in which three 1 1/4" pvc were placed in the same hole at various levels (7', 11' + 28'). The perforated section is 2' long ~~with~~ and 2" O.D. with .02" factory slots.

A temporary surface casing was placed through the gravels + then removed after the pvc was installed.

dedicated 3/8" tubing was placed in each well for sampling with peristaltic pump.

Wells were completed ~~with~~ by surging with a surge block.

FORMATION DESCRIPTION

0-6' - Coarse angular colluvial material, Cobbles are up to one foot and are all grey or green andesite. Matrix is fine sand + red-brown silt.

6'-21' Subangular to sub-rounded medium to pea-sized gravel and sand with large, random andesite cobbles. matrix contains some grey-green silt. Gravel is dominantly grey or green andesite, but quartz is also common. Fair aquifer.

21-23' possible weathered andesite bedrock

23'-30' Gray, hard andesite porphyry bedrock.

SCALE: 1" = 10'

PAGE ______ OF ______

ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

START CARD NO. ____________

PROJECT NAME: Hydrogeologic Phenomena - Mine Waste Management

COUNTY: Okanogan

WELL IDENTIFICATION NO. M2 (13, 20, 41)

LOCATION: NE ¼ NE ¼ Sec 19 Twn 33N R 22E

DRILLING METHOD: Air Rotary w/ Down hole Hammer

STREET ADDRESS OF WELL: ____________

DRILLER: ____________

FIRM: U.S.B.M.

WATER LEVEL ELEVATION: ____________

SIGNATURE: ____________

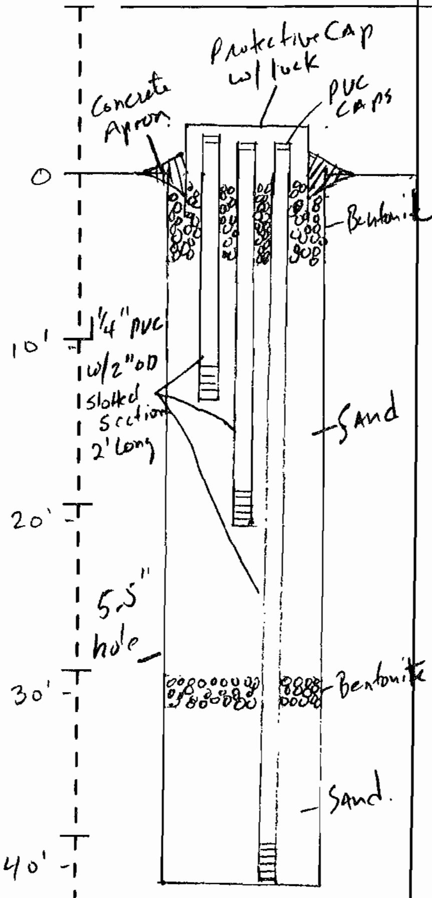
GROUND SURFACE ELEVATION: ____________

CONSULTING FIRM: ____________

INSTALLED: 7/7/87

REPRESENTATIVE: ____________

DEVELOPED: ____________

AS-BUILT	WELL DATA	FORMATION DESCRIPTION
	Same as M1. PVC ~~was~~ were placed at depths of 13', 20' & 41'.	0–10' Coarse, angular colluvial material. Cobbles are one to two feet of andesite. Matrix is angular andesite, fine sand, & red-brown silt 10'–19' Coarse sand & gravel. Cobbles up to several inches are rounded green andesite. Very minor grey-green silt. Much water & ground runs badly. 19'–27' Very coarse gravel. One foot boulders are purple slate or green andesite. Matrix is medium to coarse, subrounded to rounded green andesite. 27'–35' Medium to coarse up to 1½" gravel & sand. Gravel is rounded purple slate or black to green andesite. Runs badly 35'–40½' medium gravel (½"–¾") and sand. Gravel is rounded andesite and metasediments. Runs badly; very poor returns

Av. Water level
M2-13 ≃ ~~6.9~~ 7.3'
M2-20 ≃ ~~6.9~~ 7.3'
M2-41 ≃ ~~6.8~~ 7.2'

SCALE: 1" = 10'

PAGE ________ OF ________

ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

START CARD NO. ____________

PROJECT NAME: Hydrogeologic phenomena - Mine Waste Management

WELL IDENTIFICATION NO. M3 (16, 32)

DRILLING METHOD: Air Rotary w/ Down Hole Hammer

DRILLER:

FIRM: USBM.

SIGNATURE:

CONSULTING FIRM:

REPRESENTATIVE:

COUNTY: Okanogan

LOCATION: NE 1/4 NW 1/4 Sec 20 Twn 33N R 22E

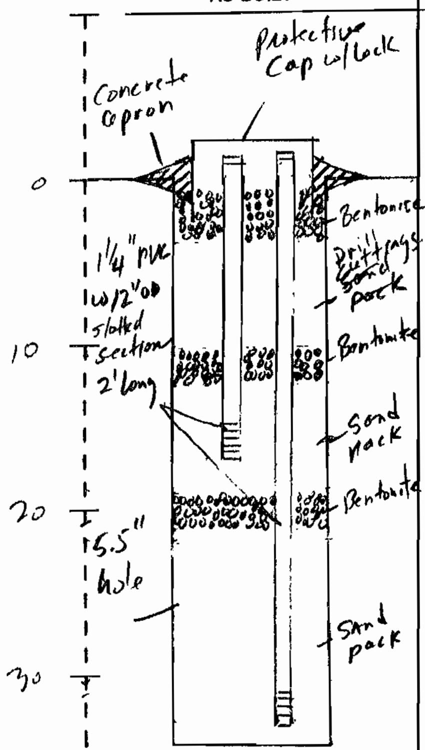
STREET ADDRESS OF WELL:

WATER LEVEL ELEVATION:

GROUND SURFACE ELEVATION:

INSTALLED: 7/14/87

DEVELOPED:

AS-BUILT	WELL DATA	FORMATION DESCRIPTION
	Same as M1, except only two PVC were installed at depths of 16' & 32'.	0-7' Coarse Colluvium of green andesite with abundant roots. Boulders are up to one foot. Matrix is small angular colluvium with red-brown silt. 7'-12' Coarse angular andesite colluvium admixed with rounded gravel matrix - some sand. 12'-13' Grey-green fine sand & silt. 13'-23' Rounded 1/4"-1/2" pea gravel of andesite, metasediment and quartz with some sand. Random Blocky cobbles (Colluvium?) Gravel content increases downward. 23'-33 1/2' Angular to subangular pea gravel with coarse random boulders and cobbles. Intersected a two foot andesite boulder at 28'.

Av. Water Level

M3-16 = No Water

M3-32 = 16.7' GL

SCALE: 1" = 10'

PAGE ________ OF ________

RESOURCE PROTECTION WELL REPORT

START CARD NO. ________

PROJECT NAME: Hydrogeologic Phenomena - Mine Waste Management

WELL IDENTIFICATION NO. M4 (17, 24, 32)

DRILLING METHOD: Air Rotary w/ Downhole Hammer

DRILLER: ________

FIRM: U.S.B.M

SIGNATURE: ________

CONSULTING FIRM: tt

REPRESENTATIVE: ________

COUNTY: OKanogan

LOCATION: NW 1/4 NW 1/4 Sec 20 Twn 33N R 22E

STREET ADDRESS OF WELL: ________

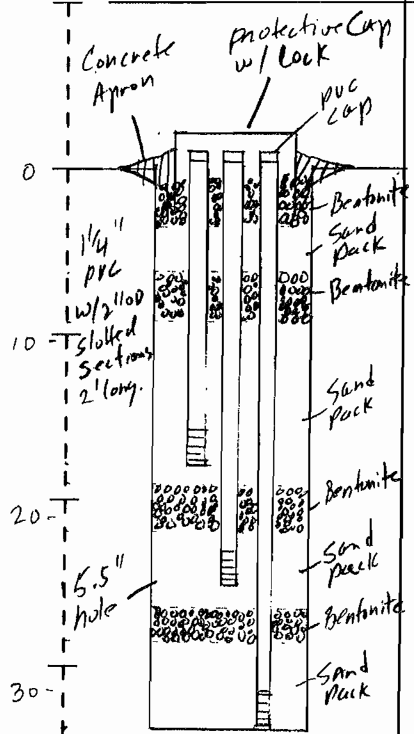
WATER LEVEL ELEVATION: ________

GROUND SURFACE ELEVATION: ________

INSTALLED: 7/15/87

DEVELOPED: ________

AS-BUILT



40

Av. water levels

M4-17 ≅ 10.9' GL

M4-24 ≅ 13.0' GL

M4-32 ≅ 11.2' GL

WELL DATA

Same as M1, PVC were placed at depths of 17', 24' & 32'.

FORMATION DESCRIPTION

0-4' fill

4'-6' old tailings

6'-11' low energy stream deposits - brown fine sand and silt with minor gravel traces.

11'-20' Rounded pea gravel of andesite and quartz with high brownish silt and fine sand content

20'-26' subrounded to subangular pea gravel with high greenish clay/silt content. Lower two feet may be weathered bedrock

26'-32' Grey andesite porphyry bedrock

SCALE: 1" = 10'

PAGE ________ OF ________

ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

START CARD NO. ______

PROJECT NAME: Hydrogeologic Phenomena – Mine Waste Management

WELL IDENTIFICATION NO. MS (13, 75, 175)

DRILLING METHOD: Direct air Rotary

DRILLER:

FIRM: U.S.B.M.

SIGNATURE:

CONSULTING FIRM:

REPRESENTATIVE:

COUNTY: Okanogan

LOCATION: NW 1/4 NW 1/4 Sec 20 Twn 33N R 22E

STREET ADDRESS OF WELL:

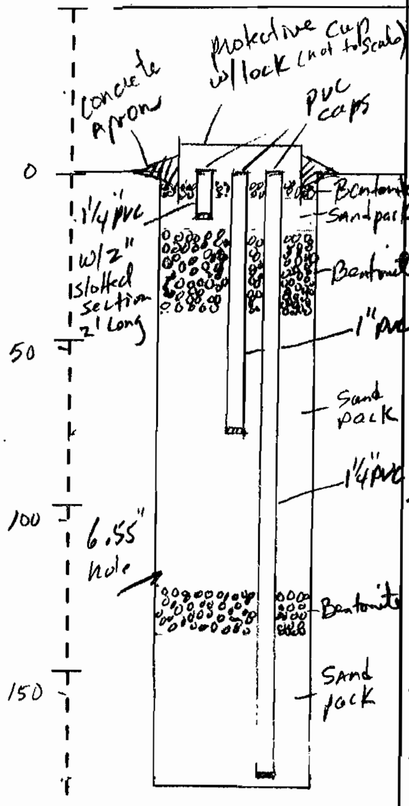
WATER LEVEL ELEVATION:

GROUND SURFACE ELEVATION:

INSTALLED: 10/23/87

DEVELOPED:

AS-BUILT



Av. water level

MS (13) ≈ 5.18' GL

MS (75) ≈ 1.0' GL

MS (175) ≈ 13.6' GL

WELL DATA

This is a multiple completed well in which ~~two~~ 1¼" + one 1" pvc were placed in the same hole at levels of 13', 75' + 175'. the 1¼" pvc have 2' long perforated sections which are 2" OD + have .02" factory slots. the 1" pvc also has a 2' long perforated section but with .01" factory slots.

A temporary surface casing was driven through the gravels + then removed after the PVC was installed.

Dedicated 3/8" tubing was installed in MS-13 + MS-75 for sampling with peristaltic pump. A dedicated 1" SS. downhole bladder pump was placed in MS-175 for sampling with a Well Wizard system.

Wells were completed by surging with a surge block + air blowing.

FORMATION DESCRIPTION

0-2' fill (Top Soil)

2'-6' Clayey, organic laden Str. dep.

6'-13' silty, pea-to-medium gravel rounded to subrounded

13'-21' Alt. hard + easy drilling. Either rubble crop of andesite or andesite boulders w/ Minor gravel.

21'-29' Hard, dark grey andesite w/ Si.

29'-100' Alternating Hard to med soft to soft zone of dark grey andesite, with 1-5' fracture zones throughout. Water at 94'.

100'-116' Hard grey andesite or diorite

116'-169' Softer grey andesite w/ some quartz fracs. Became darker @ ≈ 160'.

169'-177' fracture zones in dark grey andesite

SCALE: 1" = 50'

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ECY 050-12 (Rev. 11/89)

RESOURCE PROTECTION WELL REPORT

START CARD NO. ____

PROJECT NAME: Hydrogeologic Phenomena – Mine Waste Management

COUNTY: Okanogan

WELL IDENTIFICATION NO. BKG (21, 66, 142)

LOCATION: SE 1/4 SE 1/4 Sec 18 Twn 33N R 22E

DRILLING METHOD: Direct Air Rotary

STREET ADDRESS OF WELL:

DRILLER:

FIRM: U.S.B.M.

WATER LEVEL ELEVATION:

SIGNATURE:

GROUND SURFACE ELEVATION:

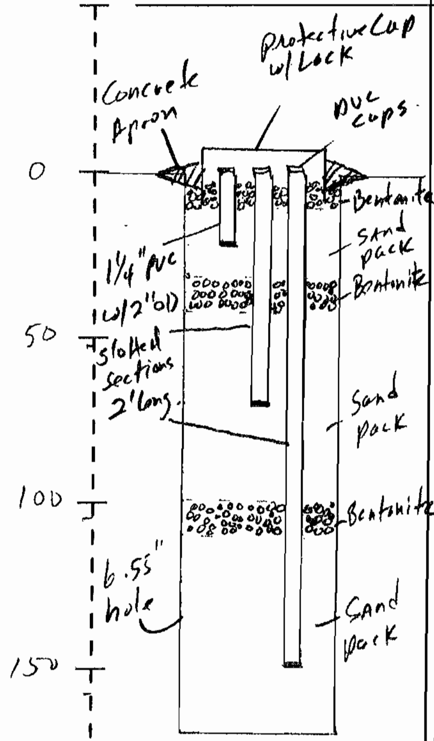
CONSULTING FIRM:

INSTALLED: 10/20/87

REPRESENTATIVE:

DEVELOPED:

AS-BUILT



Av. Water levels

BKG-21 ≅ 14.4'

BKG-66 ≅ 13.6'

BKG-142 ≅ 13.7'

WELL DATA

This is a multiple completed well in which three 1 1/4" PVC were placed in the same hole at levels of 21', 66' & 142'. The 1 1/4" PVC have 2' long perforated sections which are 2" OD & have .02" factory slots.

A temporary surface casing was driven through the gravels & then removed after the PVC was installed. Wells were completed by surging with a surge block & air blowing.

Dedicated 3/8" tubing was installed in BKG-21 for sampling with a peristaltic pump. Dedicated 1" S.S. double bladder pumps were placed in BKG-66 & BKG-142, for sampling with a well Wizard system.

FORMATION DESCRIPTION

0–2' dirt + roots (Topsoil)

2'–20' Brown silty pea-to-med. size gravel (rounded to subrounded), some sub-angular, may be mixture of alluvial + colluvial material. Wet @ 17'

20'–28' as last but larger gravels. Typically upward gravel sequence??

28'–42' Bedrock of silicified andesite. Grey-green hard.

42'–54' shattered to hard grey-green andesite

54'–110' Hard, green andesite porphyry with intermittent fracture zones (1–3')

110'–122' fractured dark grey/green andesite w/ trace of silica in fracs. Trace pyrite.

122–132 Hard dk green andesite, vein rock.

132–144' as last but fractured + easy drilling

144–157' med grey andesite w/ abundant Si, lot of water

SCALE: 1" = 50'

PAGE 1 OF 1

ECY 050-12 (Rev. 11/89)

APPENDIX B.—WATER QUALITY DATA FROM SAMPLING TRIPS BETWEEN 1988 AND 1991

Well ID	Date Sampled	Water Temp (C)	pH	Fld. Cond (uS/cm)	Eh f(mV,Temp)	Diss O2 (ppm)	DTW (m)	Pz El (m)	Neg head (m)	HCO3 (mg/l)	Al (mg/l)	B (mg/l)	Ba (mg/l)	Ca (mg/l)	Cd (mg/l)
	Background and downgradient wells														
BKG_6	02/08/88	8.2	7.2	ND	ND	ND	5.023	562.835	ND	ND	0.00	ND	ND	130	0.000
BKG_6	03/14/88	10.2	7.5	ND	ND	ND	5.252	563.046	ND	ND	0.00	0.130	0.056	150	0.000
BKG_6	04/04/88	10.5	6.8	ND	ND	ND	4.575	563.283	ND	ND	0.01	0.230	0.010	170	0.002
BKG_6	04/18/88	11.8	6.8	ND	ND	ND	4.520	563.338	ND	ND	0.00	0.170	0.017	140	0.001
BKG_6	05/09/88	15.6	7.2	ND	251	ND	4.487	563.372	ND	ND	0.02	0.177	0.017	144	0.002
BKG_6	05/30/88	12.6	7.6	ND	276	ND	4.548	563.311	ND	ND	0.03	0.173	0.021	138	0.002
BKG_6	06/20/88	11.9	7.7	ND	555	4.0	4.526	563.332	ND	ND	0.16	0.184	0.058	136	0.000
BKG_6	07/25/88	15.5	7.3	ND	544	4.5	4.807	563.052	ND	ND	0.00	0.138	0.002	127	0.001
BKG_6	08/22/88	11.5	7.0	ND	557	4.6	5.081	562.777	ND	ND	0.37	0.153	0.000	107	0.000
BKG_6	09/19/88	10.0	7.1	ND	402	4.4	5.227	562.631 ?	ND	ND	0.75 ?	0.168	0.031	127	0.001
BKG_6	10/17/88	9.9	6.4	ND	431	4.8	5.310	562.549	ND	ND	0.06	0.139	0.007	144	0.000
BKG_6	11/14/88	7.8	7.2	ND	383	5.9	5.288	562.570	ND	ND	0.12	0.177	0.027	157	0.000
BKG_6	01/09/89	9.3	7.3	ND	447	4.3	5.343	562.515	ND	ND	0.00	0.166	0.009	142	0.000
BKG_6	03/06/89	7.9	5.6	ND	450	4.4	5.313	562.546	ND	ND	0.42	0.146	0.031	131	0.010
BKG_6	04/10/89	7.9	6.9	1098	337	2.7	4.645	563.213	ND	ND	0.14	0.139	0.014	116	0.000
BKG_6	05/22/89	7.9	7.3	315	181	4.7	4.313	563.545	ND	ND	0.19	0.400	0.034	603	0.000
BKG_6	06/06/89	ND	ND	ND	ND	ND	4.307	563.552	ND	ND	ND	ND	ND	ND	ND
BKG_6	06/27/89	ND	ND	ND	ND	ND	4.380	563.478	ND	ND	ND	ND	ND	ND	ND
BKG_6	08/21/89	10.4	7.1	1160	358	3.4	4.807	563.052	ND	ND	0.52	0.330	0.034	116	0.010
BKG_6	10/30/89	8.2	7.3	139	301	3.7	5.075	562.783	ND	ND	1.58	0.160	0.056	136	0.000
BKG_6	04/30/90	ND	7.0	775	373	ND	4.612	563.247	ND	ND	0.96	0.180	0.171	128	0.000
BKG_6	06/18/90	16.2	7.4	887	471	ND	4.865	562.994	ND	340.0	0.39	0.190	0.115	141	0.000
BKG_6	03/11/91	9.3	7.1	ND	449	6.8	5.051	562.808	ND	257.4	2.28 ?	0.300	0.047	125	0.010
BKG_6	06/03/91	14.4	6.8	580	460	ND	4.944	562.915	ND	223.3	0.53	0.180	0.036	117	0.010
BKG_20	02/08/88	8.4	7.8	ND	ND	ND	4.883	562.975	ND	ND	0.00	ND	ND	38	0.000
BKG_20	03/14/88	9.0	7.4	ND	ND	ND	4.487	563.372	ND	ND	0.02	3.600	0.030	51	0.001
BKG_20	04/04/88	11.2	7.3	ND	ND	ND	4.337	563.521	ND	ND	0.00	3.800	0.022	46	0.006
BKG_20	04/18/88	15.2	7.2	ND	ND	ND	4.295	563.564	ND	ND	0.00	2.900	0.060	37	0.011
BKG_20	05/09/88	15.1	7.0	ND	86	ND	4.279	563.579	ND	ND	0.01	3.741	0.000	46	0.004
BKG_20	05/30/88	11.6	7.9	ND	185	ND	4.328	563.530	ND	ND	0.08	4.313	0.015	53	0.014
BKG_20	06/20/88	14.0	7.7	ND	251	0.4	4.325	563.533	ND	ND	0.21	4.376	0.080	51	0.003
BKG_20	07/25/88	11.0	6.6	ND	138	0.4	4.633	563.225	ND	ND	0.00	3.859	0.000	58	0.008
BKG_20	08/22/88	10.8	7.8	ND	139	0.5	4.828	563.030	ND	ND	0.47	4.573	0.000	46	0.006
BKG_20	09/19/88	9.7	7.5	ND	110	0.6	4.996	562.863 ?	ND	ND	0.75 ?	4.364	0.043	40	0.010
BKG_20	10/17/88	8.9	6.8	ND	306	0.9	5.112	562.747	ND	ND	0.11	4.728	0.010	51	0.000
BKG_20	11/14/88	7.0	7.6	ND	253	2.9	5.035	562.823	ND	ND	0.15	4.856	0.042	50	0.000
BKG_20	01/09/89	9.5	7.2	ND	205	0.5	5.127	562.732	ND	ND	0.00	4.579	0.042	50	0.010
BKG_20	03/06/89	ND	ND	ND	ND	ND	5.090	562.768	ND	ND	ND	ND	ND	ND	ND
BKG_20	04/10/89	8.6	7.7	1546	206	-0.3	4.337	563.521	ND	ND	0.15	3.761	0.029	40	0.010
BKG_20	05/22/89	8.8	8.3	1629	81	0.2	4.176	563.683	ND	ND	0.51	6.140	0.104	51	0.010
BKG_20	06/06/89	ND	ND	ND	ND	ND	4.148	563.710	ND	ND	ND	ND	ND	ND	ND
BKG_20	06/27/89	ND	ND	ND	ND	ND	4.225	563.634	ND	ND	ND	ND	ND	ND	ND
BKG_20	08/21/89	9.1	7.8	1640	200	-0.3	4.624	563.235	ND	ND	0.47	5.210	0.024	61	0.010
BKG_20	10/30/89	8.2	8.0	1353	152	-0.1	4.895	562.963	ND	ND	1.69	3.920	0.041	41	0.010

Well ID	Date Sampled	Water Temp (C)	pH	Fld. Cond (uS/cm)	Eh f(mV,Temp)	Diss O2 (ppm)	DTW (m)	Pz El (m)	Neg head (m)	HCO3 (mg/l)	Al (mg/l)	B (mg/l)	Ba (mg/l)	Ca (mg/l)	Cd (mg/l)
BKG_20	04/30/90	10.7	7.1	1119	310	ND	4.420	563.439	ND	ND	0.94	3.420	0.054	40	0.000
BKG_20	06/18/90	14.2	8.1	1383	446	ND	4.383	563.475	ND	ND	0.40	4.400	0.064	47	0.000
BKG_20	03/11/91	8.6	7.5	1110	366	1.9	4.795	563.064	ND	284.5	0.00	4.010	0.034	41	0.000
BKG_43	02/08/88	8.6	8.0	ND	ND	ND	4.795	563.064	ND	ND	0.00	ND	ND	22	0.018
BKG_43	03/14/88	10.3	7.6	ND	ND	ND	4.401	563.457	ND	ND	0.00	3.900	0.029	33	0.014
BKG_43	04/04/88	11.0	7.2	ND	ND	ND	4.270	563.588	ND	ND	0.00	5.900	0.000	40	0.042
BKG_43	04/18/88	12.7	7.2	ND	ND	ND	4.234	563.625	ND	ND	0.00	4.200	0.000	32	0.026
BKG_43	05/09/88	18.7	7.4	ND	304	ND	4.218	563.640	ND	ND	0.07	4.449	0.000	33	0.027
BKG_43	05/30/88	12.4	7.9	ND	212	ND	4.279	563.579	ND	ND	0.00	4.684	0.020	35	0.036
BKG_43	06/20/88	15.3	7.8	ND	318	0.5	4.295	563.564	ND	ND	0.18	5.616	0.060	36	0.023
BKG_43	07/25/88	11.6	7.3	ND	140	0.1	4.618	563.241	ND	ND	0.00	6.456	0.043	35	0.066
BKG_43	08/22/88	11.1	7.8	ND	229	0.6	4.849	563.009	ND	ND	0.45	5.116	0.000	33	0.026
BKG_43	09/19/88	10.4	7.7	ND	127	0.6	4.999	562.860 ?	ND	ND	0.78 ?	3.865	0.029	23	0.025
BKG_43	10/17/88	9.1	6.9	ND	385	1.0	5.063	562.796	ND	ND	0.05	5.295	0.050	38	0.020
BKG_43	11/14/88	8.6	6.8	ND	251	2.0	5.045	562.814	ND	ND	0.14	5.728	0.018	39	0.030
BKG_43	01/09/89	8.3	7.6	ND	237	0.6	5.142	562.716	ND	ND	0.00	5.155	0.015	36	0.020
BKG_43	03/06/89	ND	ND	ND	ND	ND	5.127	562.732	ND	ND	ND	ND	ND	ND	ND
BKG_43	04/10/89	9.3	7.9	1610	164	-0.4	4.694	563.164	ND	ND	0.36	4.750	0.050	61	0.030
BKG_43	05/22/89	9.3	8.4	1649	92	0.1	4.282	563.576	ND	ND	0.49	5.620	0.047	39	0.020
BKG_43	06/06/89	ND	ND	ND	ND	ND	4.243	563.616	ND	ND	ND	ND	ND	ND	ND
BKG_43	06/27/89	ND	ND	ND	ND	ND	4.307	563.552	ND	ND	ND	ND	ND	ND	ND
BKG_43	08/21/89	9.7	8.0	1596	192	-0.3	4.676	563.183	ND	ND	0.51	6.440	0.021	57	0.040
BKG_43	10/30/89	8.8	8.0	1322	134	0.3	4.953	562.905	ND	ND	1.54	4.250	0.054	33	0.030
BKG_43	04/30/90	11.0	7.6	1063	260	ND	4.526	563.332	ND	ND	0.87	3.810	0.112	30	0.020
BKG_43	06/18/90	12.9	7.2	1069	ND	ND	4.471	563.387	ND	ND	0.40	4.690	0.102	37	0.020
BKG_43	03/11/91	9.2	7.5	1100	360	2.5	4.941	562.918	ND	286.7	0.00	3.770	0.038	30	0.010
M1_2	02/08/88	6.5	6.4	ND	ND	ND	1.963	558.647	ND	ND	0.00	ND	ND	320	0.000
M1_2	03/14/88	7.1	5.9	ND	ND	ND	1.646	558.964	ND	ND	0.20	1.000	0.052	400	0.005
M1_2	04/04/88	8.1	6.1	ND	ND	ND	1.518	559.092	ND	ND	0.22	1.200	0.040	400	0.002
M1_2	04/18/88	13.4	5.7	ND	ND	ND	1.454	559.156	ND	ND	0.13	0.540	0.018	433	0.002
M1_2	05/09/88	11.0	6.1	ND	637	ND	1.518	559.092	ND	ND	0.06	0.682	0.026	389	0.000
M1_2	05/30/88	10.3	6.0	ND	313	ND	1.756	558.855	ND	ND	0.11	1.092	0.011	424	0.004
M1_2	06/20/88	18.2	6.3	ND	241	ND	1.929	558.681	ND	ND	0.19	0.980	0.031	524	0.000
M1_2	07/25/88	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_2	08/22/88	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_2	09/19/88	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_2	10/17/88	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_2	11/14/88	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_2	01/09/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_2	03/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_2	04/10/89	7.0	7.2	589	197	7.8	1.426	559.184	ND	ND	0.15	0.302	0.023	707	0.010
M1_2	05/22/89	8.6	5.8	1075	388	3.8	1.533	559.077	ND	ND	0.39	0.410	0.064	543	0.000
M1_2	06/06/89	ND	ND	ND	ND	ND	1.734	558.876	ND	ND	ND	ND	ND	ND	ND
M1_2	06/27/89	ND	ND	ND	ND	ND	1.945	558.666	ND	ND	ND	ND	ND	ND	ND
M1_2	08/21/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Well ID	Date Sampled	Water Temp (C)	pH	Fld. Cond (uS/cm)	Eh f(mV,Temp)	Diss O2 (ppm)	DTW (m)	Pz El (m)	Neg head (m)	HCO3 (mg/l)	Al (mg/l)	B (mg/l)	Ba (mg/l)	Ca (mg/l)	Cd (mg/l)
M1_2	03/12/90	7.9	3.5	3007	638	6.1	2.054	558.556	ND	ND	4.41 ?	0.250	0.168	599	0.020
M1_2	04/30/90	12.9	5.5	ND	ND	ND	1.570	559.040	ND	ND	1.05	0.250	0.078	430	0.000
M1_2	06/18/90	18.9	6.0	ND	ND	ND	1.878	558.733	ND	ND	3.05	0.250	0.041	602	0.000
M1_3	02/08/88	8.0	7.2	ND	ND	ND	1.957	558.653	ND	ND	0.00	ND	ND	340	0.000
M1_3	03/14/88	8.8	6.9	ND	ND	ND	1.524	559.086	ND	ND	0.01	0.400	0.070	230	0.012 *
M1_3	04/04/88	8.9	7.7	ND	ND	ND	1.359	559.251	ND	ND	0.00	0.360	0.030	230	0.001
M1_3	04/18/88	11.5	6.6	ND	ND	ND	1.323	559.287	ND	ND	0.16	0.320	0.025	190	0.000
M1_3	05/09/88	10.6	7.0	ND	581	ND	1.402	559.208	ND	ND	0.00	0.274	0.021	149	0.000
M1_3	05/30/88	10.3	7.3	ND	387	ND	1.649	558.961	ND	ND	0.00	0.318	0.027	162	0.000
M1_3	06/20/88	17.1	7.1	ND	166	3.6	1.765	558.845	ND	ND	0.20	0.450	0.073	213	0.000
M1_3	07/25/88	13.3	7.3	ND	152	4.0	2.326	558.285	ND	ND	0.00	0.278	0.000	158	0.001
M1_3	08/22/88	13.0	7.1	ND	162	1.3	2.603	558.007	ND	ND	0.36	0.401	0.000	125	0.001
M1_3	09/19/88	12.2	6.7	ND	259	35.0	2.719	557.891 ?	ND	ND	0.77	0.431	0.027	135	0.001
M1_3	10/17/88	10.8	7.3	ND	297	2.4	2.731	557.879	ND	ND	0.06	0.513	0.048	193	0.000
M1_3	11/14/88	9.4	6.7	ND	302	4.8	2.408	558.202	ND	ND	0.13	0.654	0.038	295	0.000
M1_3	01/09/89	8.2	7.4	ND	276	3.1	2.362	558.248	ND	ND	0.05	0.443	0.000	51567 ?	0.000
M1_3	03/06/89	7.3	6.1	ND	310	2.4	2.402	558.208	ND	ND	0.42	0.407	0.037	754	0.000
M1_3	04/10/89	9.7	7.7	2701	67	0.6	1.195	559.415	ND	ND	0.14	0.433	0.036	271	0.000
M1_3	05/22/89	8.8	7.2	402	156	2.7	1.393	559.217	ND	ND	0.33	0.440	0.027	202	0.000
M1_3	06/06/89	ND	ND	ND	ND	ND	1.591	559.019	ND	ND	ND	ND	ND	ND	ND
M1_3	06/27/89	ND	ND	ND	ND	ND	1.814	558.797	ND	ND	ND	ND	ND	ND	ND
M1_3	08/21/89	16.8	7.2	1629	175	1.0	3.039	560.610	ND	ND	0.50	0.660	0.074	165	0.000
M1_3	10/30/89	7.5	7.9	1760	121	1.7	2.478	558.132	ND	ND	1.68	0.350	0.035	173	0.000
M1_3	03/12/90	8.4	6.6	2820	189	4.2	2.015	558.595	ND	ND	0.97	0.320	0.234	570	0.020
M1_3	04/30/90	12.1	6.7	1960	225	ND	1.570	559.040	ND	ND	0.85	0.350	0.046	326	0.000
M1_3	06/18/90	15.0	7.0	1725	ND	ND	1.780	558.830	ND	ND	0.41	0.420	0.116	298	0.000
M1_3	03/11/91	7.1	6.4	3614	392	4.1	2.176	558.434	ND	642.9	0.39	0.330	0.085	740 ?	0.010
M1_3	06/03/91	15.2	6.5	2400	434	ND	2.146	558.464	ND	453.8	0.39	0.360	0.032	387	0.000
M1_8	02/08/88	9.1	6.9	ND	ND	ND	1.969	558.641	ND	ND	0.00	ND	ND	300	0.000
M1_8	03/14/88	9.9	6.7	ND	ND	ND	1.518	559.092	ND	ND	0.00	0.300	0.053	310	0.001
M1_8	04/04/88	9.4	7.4	ND	ND	ND	1.359	559.251	ND	ND	0.00	0.390	0.060	370	0.000
M1_8	04/18/88	13.7	6.4	ND	ND	ND	1.320	559.290	ND	ND	0.08	0.390	0.052	310	0.000
M1_8	05/09/88	11.6	7.3	ND	472	ND	1.411	559.199	ND	ND	0.31	0.408	0.041	296	0.000
M1_8	05/30/88	10.4	7.3	ND	351	ND	1.655	558.955	ND	ND	0.01	0.385	0.045	216	0.000
M1_8	06/20/88	17.6	7.3	ND	139	0.5	1.765	558.845	ND	ND	1.14	0.475	0.046	250	0.092
M1_8	07/25/88	11.9	7.7	ND	115	0.3	2.320	558.291	ND	ND	0.00	0.365	0.000	176	0.002
M1_8	08/22/88	12.1	7.2	ND	152	0.5	2.603	558.007	ND	ND	0.37	0.433	0.000	151	0.000
M1_8	09/19/88	10.5	6.7	ND	226	0.7	2.728	557.882 ?	ND	ND	0.71	0.435	0.053	167	0.000
M1_8	10/17/88	10.0	6.7	ND	225	0.5	2.734	557.876	ND	ND	0.07	0.500	0.050	189	0.000
M1_8	11/14/88	8.0	7.5	ND	197	2.2	2.414	558.196	ND	ND	0.17	0.584	0.099	198	0.000
M1_8	01/09/89	8.1	7.5	ND	201	2.3	2.332	558.278	ND	ND	0.00	0.558	0.052	315	0.000
M1_8	03/06/89	8.9	6.7	ND	172	4.0	2.396	558.214	ND	ND	0.42	0.442	0.045	461	0.000
M1_8	04/10/89	10.5	7.7	660	40	0.6	1.183	559.428	ND	ND	0.14	0.472	0.053	396	0.000
M1_8	05/22/89	9.5	7.3	2585	118	0.5	1.387	559.223	ND	ND	0.36	0.380	0.029	287	0.000
M1_8	06/06/89	ND	ND	ND	ND	ND	1.585	559.025	ND	ND	ND	ND	ND	ND	ND

Well ID	Date Sampled	Water Temp (C)	pH	Fld. Cond (uS/cm)	Eh f(mV,Temp)	Diss O2 (ppm)	DTW (m)	Pz El (m)	Neg head (m)	HCO3 (mg/l)	Al (mg/l)	B (mg/l)	Ba (mg/l)	Ca (mg/l)	Cd (mg/l)
M1_8	06/27/89	ND	ND	ND	ND	ND	1.795	558.815	ND	ND	ND	ND	ND	ND	ND
M1_8	08/21/89	13 4	7.3	2200	117	0.3	3.048	557.562	ND	ND	0.52	0.760	0.054	200	0.010
M1_8	10/30/89	7.5	7.3	1854	134	0.5	2.478	558.132	ND	ND	1.54	0.350	0.034	206	0.000
M1_8	03/12/90	9.0	6.6	2721	145	1.0	2.003	558.608	ND	ND	0.95	0.420	0.068	429	0.010
M1_8	04/30/90	15.2	6.9	ND	ND	ND	1.561	559.050	ND	ND	0.87	0.420	0.090	410	0.000
M1_8	06/18/90	14.1	6.9	ND	ND	ND	1.798	558.812	ND	ND	0.38	0.420	0.137	449	0.000
M1_8	03/11/91	9.7	6.7	3096	359	2.0	2.170	558.440	ND	646.6	0.00	0.530	0.094	576	0.000
M2_4	02/08/88	8.7	6.5	ND	ND	ND	2.524	558.818	ND	ND	0.00	ND	ND	180	0.000
M2_4	03/14/88	8.9	6.4	ND	ND	ND	2.295	559.047	ND	ND	0.00	0.140	0.041	260	0.002
M2_4	04/04/88	12.1	6.5	ND	ND	ND	2.067	559.275	ND	ND	0.00	0.150	0.050	270	0.002
M2_4	04/18/88	12.9	6.0	ND	ND	ND	2.009	559.333	ND	ND	0.26	0.160	0.070	270	0.000
M2_4	05/09/88	13.1	6.7	ND	332	ND	2.057	559.284	ND	ND	0.02	0.214	0.010	307	0.001
M2_4	05/30/88	9.7	6.4	ND	347	ND	2.277	559.065	ND	ND	0.00	0.119	0.048	310	0.000
M2_4	06/20/88	20.8	6.2	ND	398	ND	2.402	558.940	ND	ND	0.15	0.087	0.035	277	0.002
M2_4	07/25/88	11.2	7.2	ND	415	0.6	2.914	558.428	ND	ND	0.00	0.567	0.000 ?	259	0.000
M2_4	08/22/88	11.7	6.1	ND	370	0.7	3.152	558.190	ND	ND	0.36	0.191	0.000	210	0.001
M2_4	09/19/88	11.2	5.0	ND	464	1.4	3.277	558.065 ?	ND	ND	0.74	0.196	0.027	223	0.000
M2_4	10/17/88	10.8	6.1	ND	367	2.2	3.286	558.056	ND	ND	0.05	0.222	0.044	324	0.000
M2_4	11/14/88	5.4	7.8	ND	383	6.0	2.969	558.373 ?	ND	ND	0.10 ?	0.128	0.083 ?	58 ?	0.000
M2_4	01/09/89	8.0	6.8	ND	390	1.9	2.947	558.394	ND	ND	0.00	0.160	0.041	325	0.000
M2_4	03/06/89	8.8	6.2	ND	569	2.7	2.957	558.385	ND	ND	0.41	0.161	0.026	297	0.010
M2_4	04/10/89	10.4	6.4	3033	196	6.9	1.981	559.361	ND	ND	0.13	0.232	0.043	315	0.000
M2_4	05/22/89	8.6	6.3	2500	290	0.3	2.012	559.330	ND	ND	0.46	0.320	0.067	323	0.000
M2_4	06/06/89	ND	ND	ND	ND	ND	2.185	559.156	ND	ND	ND	ND	ND	ND	ND
M2_4	06/27/89	ND	ND	ND	ND	ND	2.390	558.952	ND	ND	ND	ND	ND	ND	ND
M2_4	08/21/89	10.7	6.4	2811	309	2.8	3.039	558.303	ND	ND	0.54	0.210	0.038	257	0.010
M2_4	10/30/89	9.7	6.4	2444	327	0.3	3.039	558.303	ND	ND	1.75	0.120	0.045	339	0.000
M2_4	03/12/90	8.3	8.6	2200	397	0.5	2.612	558.730	ND	240.0	1.05	0.140	0.195	303	0.010
M2_4	04/30/90	15.3	6.0	1861	ND	ND	2.185	559.156	ND	ND	0.94	0.130	0.045	312	0.000
M2_4	06/18/90	14.4	6.1	1882	ND	ND	2.368	558.973	ND	ND	0.46	0.160	0.097	332	0.000
M2_6	02/08/88	9.7	6.7	ND	ND	ND	2.533	558.809	ND	ND	0.00	ND	ND	210	0.000
M2_6	03/14/88	10.1	6.4	ND	ND	ND	2.304	559.037	ND	ND	0.00	0.200	0.082	260	0.005
M2_6	04/04/88	11.2	6.2	ND	ND	ND	2.070	559.272	ND	ND	0.01	0.200	0.045	360	0.002
M2_6	04/18/88	12.2	6.0	ND	ND	ND	2.003	559.339	ND	ND	0.05	0.160	0.059	270	0.001
M2_6	05/09/88	14.1	6.7	ND	330	ND	2.051	559.290	ND	ND	0.02	0.167	0.029	311	0.001
M2_6	05/30/88	6.5	6.5	ND	319	ND	2.277	559.065	ND	ND	0.13	0.133.	0.078	203	0.001
M2_6	06/20/88	14.6	6.2	ND	289	0.2	2.362	558.980	ND	ND	0.00	0.114	0.042	273	0.002
M2_6	07/25/88	11.7	7.1	ND	323	0.6	2.929	558.413	ND	ND	0.00	0.145	0.000	257	0.003
M2_6	08/22/88	11.2	6.3	ND	373	0.6	3.173	558.169	ND	ND	0.33	0.160	0.000	218	0.000
M2_6	09/19/88	10.6	6.0	ND	398	0.8	3.295	558.047 ?	ND	ND	0.68	0.211	0.033	236	0.000
M2_6	10/17/88	10.0	6.0	ND	371	1.7	3.328	558.013	ND	ND	0.05	0.194	0.056	343	0.000
M2_6	11/14/88	7.1	7.0	ND	377	3.4	3.002	558.339 ?	ND	ND	0.11 ?	0.103	0.093 ?	57 ?	0.000
M2_6	01/09/89	9.1	7.1	ND	355	1.7	2.978	558.364	ND	ND	0.44	0.257	0.064	343	0.000
M2_6	03/06/89	8.7	6.3	ND	533	1.0	3.002	558.339	ND	ND	0.43	0.151	0.045	347	0.010
M2_6	04/10/89	11.3	7.0	2768	139	0.1	1.981	559.361	ND	ND	0.13	0.350	0.043	327	0.000

Well ID	Date Sampled	Water Temp (C)	pH	Fld. Cond (uS/cm)	Eh f(mV,Temp)	Diss O2 (ppm)	DTW (m)	Pz El (m)	Neg head (m)	HCO3 (mg/l)	Al (mg/l)	B (mg/l)	Ba (mg/l)	Ca (mg/l)	Cd (mg/l)
M2_6	05/22/89	9.1	6.3	2728	320	0.2	1.951	559.391	ND	ND	0.40	0.100	0.027	297	0.000
M2_6	06/06/89	ND	ND	ND	ND	ND	2.176	559.165	ND	ND	ND	ND	ND	ND	ND
M2_6	06/27/89	ND	ND	ND	ND	ND	2.384	558.958	ND	ND	ND	ND	ND	ND	ND
M2_6	08/21/89	9.7	6.4	1762	319	0.2	3.048	558.294	ND	ND	0.50	0.260	0.056	279	0.010
M2_6	10/30/89	9.3	6.5	1829	326	0.3	3.072	558.269	ND	ND	1.71	0.460	0.026	226	0.000
M2_6	03/12/90	9.1	8.7	2162	373	0.7	2.643	558.699	ND	ND	0.96	0.120	0.183	261	0.000
M2_6	04/30/90	14.3	6.0	1846	ND	ND	2.195	559.147	ND	ND	0.87	0.240	0.164	306	0.000
M2_6	06/18/90	13.5	6.3	1853	ND	ND	2.374	558.967	ND	ND	0.36	0.130	0.089	304	0.000
M2_12	02/08/88	9.4	6.9	ND	ND	ND	2.737	558.605	ND	ND	0.00	ND	ND	240	0.000
M2_12	03/14/88	9.9	6.8	ND	ND	ND	2.067	559.275	ND	ND	0.00	0.680	0.071	300	0.009
M2_12	04/04/88	12.6	6.5	ND	ND	ND	1.820	559.522	ND	ND	0.00	0.760	0.054	410	0.000
M2_12	04/18/88	13.4	6.5	ND	ND	ND	1.795	559.546	ND	ND	0.00	0.510	0.033	340	0.000
M2_12	05/09/88	12.8	7.2	ND	193	ND	1.881	559.461	ND	ND	0.01	0.602	0.014	336	0.005
M2_12	05/30/88	7.0	7.0	ND	332	ND	2.198	559.144	ND	ND	0.03	0.531	0.049	302	0.000
M2_12	06/20/88	12.9	6.5	ND	223	0.3	2.317	559.025	ND	ND	0.13	0.370	0.045	292	0.001
M2_12	07/25/88	12.1	7.5	ND	219	0.5	2.871	558.470	ND	ND	0.00	0.230	0.000	245	0.005
M2_12	08/22/88	11.4	6.9	ND	249	0.2	3.176	558.166	ND	ND	0.38	0.519	0.000	216	0.000
M2_12	09/19/88	10.7	6.6	ND	329	0.6	3.307	558.035 ?	ND	ND	0.72 ?	0.525	0.021	214	0.000
M2_12	10/17/88	9.9	6.3	ND	342	1.2	3.335	558.007	ND	ND	0.06	0.600	0.059	323	0.000
M2_12	11/14/88	6.9	7.5	ND	375	5.1	3.133	558.208 ?	ND	ND	0.12 ?	0.319	0.086 ?	186 ?	0.000
M2_12	01/09/89	8.8	7.7	ND	278	0.9	3.158	558.184	ND	ND	0.00	0.663	0.056	255	0.000
M2_12	03/06/89	8.6	6.2	ND	496	1.5	3.170	558.172	ND	ND	0.43	0.571	0.029	244	0.010
M2_12	04/10/89	11.5	7.4	2831	119	0.2	1.387	559.955	ND	ND	0.11	0.682	0.045	329	0.010
M2_12	05/22/89	9.7	7.0	1888	239	0.2	1.890	559.452	ND	ND	0.31	0.340	0.048	301	0.000
M2_12	06/06/89	ND	ND	ND	ND	ND	2.100	559.242	ND	ND	ND	ND	ND	ND	ND
M2_12	06/27/89	ND	ND	ND	ND	ND	2.332	559.010	ND	ND	ND	ND	ND	ND	ND
M2_12	08/21/89	10.4	7.2	1653	253	-0.5	3.069	558.272	ND	ND	0.52	0.520	0.029	200	0.010
M2_12	10/30/89	9.2	7.1	1604	235	0.3	3.219	558.123	ND	ND	1.75	0.130	0.045	323	0.010
M2_12	03/12/90	9.3	6.4	1592	279	0.5	2.737	558.605	ND	ND	0.99	0.500	0.231	201	0.010
M2_12	04/30/90	14.2	6.9	1238	ND	ND	2.179	559.162	ND	ND	0.84	0.550	0.039	198	0.000
M2_12	06/18/90	14.0	7.1	1280	ND	ND	2.414	558.928	ND	ND	0.37	0.490	0.041	215	0.000
M3_10	02/08/88	9.0	6.9	ND	ND	ND	5.791	548.409	ND	ND	0.00	ND	ND	260	0.000
M3_10	03/14/88	ND	ND	ND	ND	ND	5.514	548.686	ND	ND	0.00	0.300	0.080	220	0.000
M3_10	04/04/88	8.8	7.6	ND	ND	ND	5.139	549.061	ND	ND	0.02	0.380	0.038	250	0.000
M3_10	04/18/88	11.7	7.0	ND	ND	ND	4.904	549.296	ND	ND	0.09	0.290	0.087	200	0.000
M3_10	05/09/88	12.6	7.4	ND	189	ND	4.764	549.436	ND	ND	0.00	0.255	0.032	196	0.001
M3_10	05/30/88	9.5	7.5	ND	227	ND	5.011	549.189	ND	ND	0.00	0.389	0.021	209	0.001
M3_10	06/20/88	15.4	7.5	ND	234	ND	4.270	549.930	ND	ND	0.20	0.327	0.116	252	0.000
M3_10	07/25/88	10.8	8.6	ND	189	0.6	5.459	548.741	ND	ND	0.00	0.289	0.013	203	0.004
M3_10	08/22/88	12.0	7.6	ND	155	0.9	6.218	547.982	ND	ND	0.37	0.276	0.000	158	0.000
M3_10	09/19/88	10.9	7.0	ND	220	0.8	6.578	547.623 ?	ND	ND	0.71 ?	0.317	0.021	196	0.000
M3_10	10/17/88	9.2	6.6	ND	256	1.4	6.648	547.552	ND	ND	0.04	0.343	0.030	274	0.000
M3_10	11/14/88	8.4	6.2	ND	288	4.4	6.471	547.729	ND	ND	0.11	0.354	0.026	206	0.000
M3_10	01/09/89	8.5	6.8	ND	195	1.8	6.157	548.043	ND	ND	0.00	0.316	0.051	239	0.000
M3_10	03/06/89	7.3	6.2	ND	192	1.2	5.950	548.250	ND	ND	0.39	0.325	0.046	233	0.000

Well ID	Date Sampled	Water Temp (C)	pH	Fld. Cond (uS/cm)	Eh f(mV,Temp)	Diss O2 (ppm)	DTW (m)	Pz El (m)	Neg head (m)	HCO3 (mg/l)	Al (mg/l)	B (mg/l)	Ba (mg/l)	Ca (mg/l)	Cd (mg/l)
M3_10	04/10/89	10.2	7.3	875	58	0.8	5.029	549.171	ND	ND	0.15	0.318	0.039	226	0.000
M3_10	05/22/89	8.6	7.3	1594	160	0.3	4.484	549.717	ND	ND	0.27	0.270	0.031	219	0.000
M3_10	06/06/89	ND	ND	ND	ND	ND	4.764	549.436	ND	ND	ND	ND	ND	ND	ND
M3_10	06/27/89	ND	ND	ND	ND	ND	5.084	549.116	ND	ND	ND	ND	ND	ND	ND
M3_10	08/21/89	12.0	7.3	419	165	3.3	6.090	548.110	ND	ND	0.52	0.380	0.043	234	0.010
M3_10	10/30/89	8.4	7.2	1698	173	0.4	6.437	547.763	ND	ND	1.81	0.240	0.054	224	0.000
M3_10	03/12/90	8.8	8.4	1719	187	3.4	5.743	548.458	ND	ND	0.95	0.240	0.036	204	0.010
M3_10	04/30/90	12.6	7.0	1260	ND	ND	5.093	549.107	ND	ND	0.87	0.300	0.043	217	0.000
M3_10	06/18/90	13.4	6.7	1212	ND	ND	5.166	549.034	ND	ND	0.38	0.290	0.058	267	0.000
M3_10	03/11/91	ND	ND	ND	ND	ND	5.944	0.000	ND	ND	ND	ND	ND	ND	ND
M4_5	02/08/88	8.0	6.7	ND	ND	ND	3.621	549.073	ND	ND	0.04	ND	ND	770	0.000
M4_5	03/14/88	8.6	ND	ND	ND	ND	3.679	549.015	ND	ND	0.00	0.410	0.054	400	0.004
M4_5	04/04/88	10.0	6.8	ND	ND	ND	3.353	549.342	ND	ND	0.00	0.430	0.051	590	0.002
M4_5	04/18/88	11.2	6.7	ND	ND	ND	3.197	549.497	ND	ND	0.00	0.220	0.030	500	0.003
M4_5	05/09/88	16.3	6.7	ND	559	ND	3.106	549.589	ND	ND	0.00	0.230	0.030	558	0.000
M4_5	05/30/88	ND	6.6	ND	531	ND	3.344	549.351	ND	ND	0.06	0.259	0.030	624	0.004
M4_5	06/20/88	14.3	7.0	ND	459	0.7	3.469	549.226	ND	ND	0.17	0.256	0.055	793	0.000
M4_5	07/25/88	10.6	9.0	ND	255	5.4	3.804	548.891	ND	ND	0.00	0.504	0.000	607	0.003
M4_5	08/22/88	17.4	7.0	ND	415	4.8	4.554	548.141	ND	ND	0.43	0.285	0.000	438	0.000
M4_5	09/19/88	13.1	6.7	ND	537	3.4	4.807	547.888 ?	ND	ND	0.69 ?	0.343	0.049	608	0.000
M4_5	11/14/88	5.5	6.6	ND	532	6.4	4.676	548.019	ND	ND	0.14	0.467	0.030	794	0.000
M4_5	01/09/89	6.9	6.8	ND	424	5.1	4.407	548.287	ND	ND	0.00	0.472	0.051	835	0.000
M4_5	03/06/89	11.1	6.3	ND	330	2.5	4.124	548.570	ND	ND	0.98	0.296	0.035	806	0.020
M4_5	04/10/89	9.7	7.0	2811	195	1.7	3.304	549.390	ND	ND	0.29	0.241	0.026	448	0.000
M4_5	05/22/89	8.4	6.9	3497	324	4.4	2.877	549.817	ND	ND	0.40	0.300	0.039	447	0.000
M4_5	06/06/89	ND	ND	ND	ND	ND	3.133	549.561	ND	ND	ND	ND	ND	ND	ND
M4_5	06/27/89	ND	ND	ND	ND	ND	3.396	549.299	ND	ND	ND	ND	ND	ND	ND
M4_5	08/21/89	16.8	6.5	4539	336	1.5	4.310	548.385	ND	ND	0.50	0.380	0.046	392	0.020
M4_5	10/30/89	ND	ND	ND	ND	ND	4.679	548.016	ND	ND	1.75	0.220	0.035	633	0.000
M4_5	03/12/90	8.2	6.4	3350	378	3.5	3.901	548.793	ND	470.0	1.07	0.240	0.172	615	0.010
M4_5	04/30/90	15.4	6.6	ND	ND	ND	3.328	549.366	ND	ND	0.95	0.220	0.042	662	0.000
M4_5	06/18/90	14.2	6.6	ND	ND	ND	3.429	549.265	ND	480.0	0.38	0.250	0.116	661	0.000
M4_5	03/11/91	10.0	6.7	3420	511	5.6	4.075	548.619	ND	398.9	1.65	0.290	0.092	814	0.000
M4_5	06/03/91	14.4	6.8	3590	495	ND	3.737	548.958	ND	439.2	0.42	0.210	0.093	699	0.000
M4_7	02/08/88	6.9	7.0	ND	ND	ND	4.045	548.650	ND	ND	0.00	ND	ND	710	0.000
M4_7	03/14/88	ND	ND	ND	ND	ND	3.667	549.028	ND	ND	0.00	0.470	0.100	420	0.009
M4_7	04/04/88	11.2	7.0	ND	ND	ND	3.435	549.259	ND	ND	0.01	0.490	0.017	520	0.002
M4_7	04/18/88	13.8	7.1	ND	ND	ND	3.264	549.430	ND	ND	0.42	0.300	0.045	530	0.002
M4_7	05/09/88	12.7	6.0	ND	410	ND	3.207	549.488	ND	ND	0.24	0.180	0.026 ?	551	0.002
M4_7	05/30/88	ND	6.9	ND	459	ND	3.420	549.275	ND	ND	0.00	0.328	0.018	678	0.004
M4_7	06/20/88	12.6	7.5	ND	332	ND .	3.536	549.159	ND	ND	0.15	0.401	0.046	729	0.000
M4_7	07/25/88	25.8	8.2	ND	313	8.3	4.630	548.064	ND	ND	0.00	0.347	0.000	509	0.006
M4_7	08/22/88	16.6	7.1	ND	349	6.7	4.569	548.125	ND	ND	0.39	0.345	0.000	426	0.004
M4_7	09/19/88	13.0	6.7	ND	468	4.3	4.810	547.885 ?	ND	ND	0.71 ?	0.342	0.013	560	0.001
M4_7	10/17/88	9.5	6.6	ND	403	10.8	4.892	547.802	ND	ND	0.06	0.325	0.018	943	0.000

Well ID	Date Sampled	Water Temp (C)	pH	Fld. Cond (uS/cm)	Eh f(mV,Temp)	Diss O2 (ppm)	DTW (m)	Pz El (m)	Neg head (m)	HCO3 (mg/l)	Al (mg/l)	B (mg/l)	Ba (mg/l)	Ca (mg/l)	Cd (mg/l)
M4_7	11/14/88	5.9	6.4	ND	418	8.5	4.755	547.940	ND	ND	0.09	0.389	0.008	793	0.000
M4_7	01/09/89	8.0	7.0	ND	412	4.7	4.481	548.214	ND	ND	0.00	0.373	0.096	808	0.000
M4_7	03/06/89	7.9	6.0	ND	436	4.0	4.228	548.467	ND	ND	0.62	0.341	0.013	687	0.010
M4_7	04/10/89	13.8	6.9	365	131	4.6	3.252	549.442	ND	ND	0.14	0.315	0.027	653	0.010
M4_7	05/22/89	9.2	7.0	294	324	4.0	2.993	549.701	ND	ND	0.28	0.760	0.047	576	0.000
M4_7	06/06/89	ND	ND	ND	ND	ND	3.261	549.433	ND	ND	ND	ND	ND	ND	ND
M4_7	06/27/89	ND	ND	ND	ND	ND	3.520	549.174	ND	ND	ND	ND	ND	ND	ND
M4_7	08/21/89	14.5	6.7	4430	284	1.5	4.423	548.272	ND	ND	0.52	0.570	0.030	497	0.000
M4_7	10/30/89	6.6	7.6	3969	267	2.2	4.813	547.882	ND	ND	1.62	0.270	0.028	614	0.000
M4_7	03/12/90	9.1	6.7	4779	313	4.2	3.953	548.741	ND	ND	1.13	0.270	0.129	658	0.000
M4_7	04/30/90	17.3	6.8	ND	ND	ND	3.514	549.180	ND	ND	1.16	0.260	0.039	629	0.000
M4_7	06/18/90	15.4	7.0	ND	ND	ND	3.621	549.073	ND	ND	0.45	0.260	0.109	615	0.000
M4_7	03/11/91	9.0	6.8	3380	484	4.3	4.243	548.452	ND	542.9	1.72	0.290	0.039	655	0.000
M4_10	02/08/88	7.0	7.7	ND	ND	ND	4.133	548.561	ND	ND	0.01	ND	ND	160 ?	0.000
M4_10	03/14/88	ND	ND	ND	ND	ND	3.706	548.988	ND	ND	0.00	0.340	0.071	240	0.005
M4_10	04/04/88	10.9	7.3	ND	ND	ND	3.499	549.195	ND	ND	0.00	0.323	0.039	382	0.004
M4_10	04/18/88	17.4	7.0	ND	ND	ND	3.298	549.396	ND	ND	0.05	0.400	0.092	330	0.001
M4_10	05/09/88	20.7	7.3	ND	332	ND	3.274	549.421	ND	ND	0.00	0.258	0.077	356	0.000
M4_10	05/30/88	ND	7.2	ND	400	ND	3.450	549.244	ND	ND	0.00	0.501	0.030	481	0.000
M4_10	06/20/88	19.7	7.5	ND	291	ND	3.594	549.101	ND	ND	0.17	0.341	0.082	626	0.000
M4_10	07/25/88	12.7	7.1	ND	243	5.4	3.975	548.720	ND	ND	0.00	0.327	0.000	410	0.003
M4_10	08/22/88	17.9	7.3	ND	303	5.3	4.642	548.052	ND	ND	0.41	0.507	0.000	404	0.003
M4_10	09/19/88	15.6	6.7	ND	350	9.4	4.859	547.836 ?	ND	ND	0.76 ?	0.315	0.025	407	0.001
M4_10	10/17/88	9.9	6.6	ND	371	8.1	4.944	547.751	ND	ND	0.00	0.303	0.061	768	0.000
M4_10	11/14/88	5.9	6.4	ND	418	8.5	4.785	547.909	ND	ND	0.33	0.518	0.033	841	0.000
M4_10	01/09/89	7.9	6.8	ND	233	6.7	4.560	548.135	ND	ND	0.00	0.350	0.032	657	0.000
M4_10	03/06/89	10.7	7.0	ND	214	7.9	4.368	548.327	ND	ND	0.44	0.308	0.009	710	0.010
M4_10	04/10/89	14.4	7.1	2411	93	3.8	3.286	549.409	ND	ND	0.15	0.480	0.035	588	0.010
M4_10	05/22/89	9.6	7.1	4427	210	5.6	3.094	549.601	ND	ND	0.50	0.620	0.034	610	0.000
M4_10	06/06/89	ND	ND	ND	ND	ND	3.353	549.342	ND	ND	ND	ND	ND	ND	ND
M4_10	06/27/89	ND	ND	ND	ND	ND	3.630	549.064	ND	ND	ND	ND	ND	ND	ND
M4_10	08/21/89	14.7	6.8	4316	219	1.0	0.000	546.946	ND	ND	0.55	0.940	0.034	746	0.020 *
M4_10	10/30/89	5.0	7.1	4397	227	3.4	4.865	547.830	ND	ND	1.75	0.400	0.049	662	0.030 *
M4_10	03/12/90	9.2	6.8	3759	210	3.2	4.048	0.000	ND	ND	1.16	0.640	0.032	697	0.000
M4_10	04/30/90	16.4	6.9	ND	ND	ND	3.621	549.073	ND	ND	0.95	0.680	0.059	646	0.000
M4_10	06/18/90	16.2	6.9	ND	ND	ND	3.716	548.979	ND	ND	0.43	0.610	0.110	645	0.000
M4_10	03/11/91	9.2	6.8	3000	455	6.4	4.359	548.336	ND	ND	0.00	0.640	0.082	806	0.000
M5_4	02/08/88	6.8	7.1	ND	ND	ND	2.067	543.989	ND	ND	0.00	ND	ND	410	0.000
M5_4	03/14/88	7.8	7.0	ND	ND	ND	1.804	544.251	ND	ND	0.00	0.320	0.088	330	0.003
M5_4	04/04/88	6.0	6.7	ND	ND	ND	1.554	544.501	ND	ND	0.04	0.390	0.075	440	0.003
M5_4	04/18/88	10.0	7.0	ND	ND	ND	1.594	544.462	ND	ND	0.08	0.240	0.096	360	0.002
M5_4	05/09/88	11.9	7.0	ND	376	ND	1.686	544.370	ND	ND	0.02	0.238	0.030	349	0.000
M5_4	05/30/88	10.2	7.1	ND	ND	ND	1.841	544.215	ND	ND	0.00	0.279	0.056	462	0.003
M5_4	06/20/88	12.2	7.4	ND	445	ND	1.945	544.111	ND	ND	0.12	0.238	0.063	446	0.000
M5_4	07/25/88	10.8	6.5	ND	268	2.1	ND	ND	ND	ND	0.00	0.285	0.000	354	0.002

Well ID	Date Sampled	Water Temp (C)	pH	Fld. Cond (uS/cm)	Eh f(mV,Temp)	Diss O2 (ppm)	DTW (m)	Pz El (m)	Neg head (m)	HCO3 (mg/l)	Al (mg/l)	B (mg/l)	Ba (mg/l)	Ca (mg/l)	Cd (mg/l)
M5_4	08/22/88	12.0	7.3	ND	431	5.8	2.914	543.142	ND	ND	0.36	0.320	0.000	278	0.000
M5_4	09/19/88	16.9	7.1	ND	404	ND	3.018	543.038	ND	ND	ND	0.344	0.028	315	0.000
M5_4	10/17/88	9.8	6.7	ND	565	8.7	2.883	543.172	ND	ND	0.06	0.283	0.092	437	0.000
M5_4	11/14/88	8.3	7.3	ND	287	6.4	2.606	543.450	ND	ND	0.20	0.753	0.032 ?	204	0.010
M5_4	01/09/89	8.6	7.4	ND	290	3.6	2.384	543.672	ND	ND	0.00	0.234	0.035	472	0.000
M5_4	03/06/89	7.4	6.9	ND	409	3.0	2.195	543.861	ND	ND	0.41	0.305	0.021	447	0.010
M5_4	04/10/89	6.3	7.3	2781	266	4.9	1.393	544.663	ND	ND	0.14	0.290	0.098	398	0.000
M5_4	05/22/89	6.6	7.2	3383	293	4.9	1.646	544.410	ND	ND	0.49	0.290	0.082	573	0.000
M5_4	06/06/89	ND	ND	ND	ND	ND	1.756	544.300	ND	ND	ND	ND	ND	ND	ND
M5_4	06/27/89	ND	ND	ND	ND	ND	1.939	544.117	ND	ND	ND	ND	ND	ND	ND
M5_4	08/21/89	11.1	6.9	2599	279	2.1	2.807	543.249	ND	ND	0.56	0.290	0.038	420	0.020 *
M5_4	10/30/89	9.1	6.9	3002	305	6.8	2.658	543.398	ND	ND	1.72 ?	0.210	0.048	368	0.000
M5_4	03/12/90	7.5	7.2	1695	345	5.0	1.945	544.111	ND	410.0	0.99	0.200	0.197	409	0.010
M5_4	04/30/90	9.6	7.8	ND	ND	ND	1.807	544.248	ND	ND	0.99	0.240	0.038	397	0.000
M5_4	06/18/90	14.1	7.1	ND	ND	ND	1.890	544.166	ND	470.0	0.41	0.370	0.136	375	0.000
M5_4	03/11/91	7.8	7.0	2430	482	4.9	2.057	543.998	ND	423.3	0.00	0.170	0.093	411	0.000
M5_4	06/03/91	12.0	6.8	1390	460	ND	2.121	543.934	ND	389.2	0.39	0.310	0.070	363	0.000
M5_23	02/08/88	4.3	8.0	ND	ND	ND	0.649	545.407	ND	ND	0.00	ND	ND	58	0.000
M5_23	03/14/88	15.5	7.0	ND	ND	ND	0.241	545.815	ND	ND	0.00	1.100	0.120	79	0.000
M5_23	04/04/88	8.8	8.1	ND	ND	ND	-0.049	546.105	ND	ND	0.00	1.400	0.026	86	0.000
M5_23	04/18/88	17.9	7.1	ND	ND	ND	-0.223	546.278	ND	ND	0.22	1.200	0.150	68	0.000
M5_23	05/09/88	13.8	7.7	ND	422	ND	-0.137	546.193	ND	ND	0.00	0.897	0.034	56	0.000
M5_23	05/30/88	11.9	7.6	ND	541	ND	-0.162	546.217	ND	ND	0.00	1.475	0.074	96	0.005
M5_23	06/20/88	23.2	6.7	ND	310	ND	-0.064	546.120	ND	ND	0.18	1.501	0.156	83	0.000
M5_23	07/25/88	14.5	7.1	ND	419	5.7	0.567	545.489	ND	ND	0.00	1.470	0.075	84	0.003
M5_23	08/22/88	15.6	8.2	ND	380	1.6	0.927	545.129	ND	ND	0.37	1.023	0.000	57	0.000
M5_23	09/19/88	12.5	7.3	ND	324	7.4	1.302	544.754 ?	ND	ND	0.76 ?	1.293	0.065	65	0.002
M5_23	10/17/88	9.2	7.3	ND	453	9.1	1.506	544.550	ND	ND	0.02	1.174	0.025	72	0.000
M5_23	11/14/88	7.9	7.6	ND	350	5.6	1.500	544.556	ND	ND	0.28	1.035	0.039	198 ?	0.020
M5_23	01/09/89	8.7	7.5	ND	400	10.4	1.448	544.608	ND	ND	0.00	1.197	0.059	73	0.000
M5_23	03/06/89	10.4	6.8	ND	325	3.0	1.308	544.748	ND	ND	0.51	1.592	0.070	139	0.000
M5_23	04/10/89	11.5	8.2	186	187	2.6	-0.037	546.092	ND	ND	0.14	1.128	0.059	61	0.000
M5_23	05/22/89	8.8	7.9	770	214	2.4	-0.311	546.367	ND	ND	0.46	1.420	0.053	81	0.000
M5_23	06/27/89	ND	ND	ND	ND	ND	0.213	545.842	ND	ND	ND	ND	ND	ND	ND
M5_23	08/21/89	17.2	7.5	1158	198	1.9	0.695	545.361	ND	ND	0.47	1.450	0.046	75	0.010
M5_23	10/30/89	5.2	7.8	483	206	1.8	1.804	544.251	ND	ND	1.65	1.080	0.026	70	0.000
M5_23	03/12/90	10.4	7.3	597	255	0.5	0.762	545.294	ND	ND	1.02	1.230	0.168	73	0.020
M5_23	04/30/90	12.0	8.0	724	ND	ND	0.265	545.791	ND	ND	0.88	0.990	0.158	64	0.000
M5_23	06/18/90	17.1	7.8	709	ND	ND	0.280	545.775	ND	ND	0.37	1.220	0.116	76	0.000
M5_23	03/11/91	8.2	7.6	ND	ND	ND	0.896	545.160	ND	175.7	1.65	1.080	0.050	63	0.000
M5_53	12/09/87	ND	8.4	ND	ND	ND	5.130	540.926	ND	ND	0.41	ND	ND	13	0.001
M5_53	02/08/88	9.3	8.3	ND	ND	ND	4.883	541.173	ND	ND	0.00	ND	ND	20	0.000
M5_53	03/14/88	10.9	8.3	ND	ND	ND	4.371	541.685	ND	ND	0.01	2.000	0.120	13	0.000
M5_53	04/04/88	10.9	8.5	ND	ND	ND	4.106	541.950	ND	ND	0.00	2.400	0.010	15	0.000
M5_53	04/18/88	ND	8.2	ND	ND	ND	3.889	542.167	ND	ND	0.11	2.200	0.030	13	0.000

Well ID	Date Sampled	Water Temp (C)	pH	Fld. Cond (uS/cm)	Eh f(mV,Temp)	Diss O2 (ppm)	DTW (m)	Pz El (m)	Neg head (m)	HCO3 (mg/l)	Al (mg/l)	B (mg/l)	Ba (mg/l)	Ca (mg/l)	Cd (mg/l)
M5_53	05/09/88	14.4	8.2	ND	245	ND	3.926	542.130	ND	ND	0.00	1.846	0.016	9	0.000
M5_53	05/30/88	13.4	8.9	ND	ND	ND	4.011	542.045	ND	ND	0.03	2.688	0.061	13	0.000
M5_53	06/20/88	18.3	8.0	ND	210	ND	4.103	541.953	ND	ND	0.18	2.833	0.054	14	0.000
M5_53	07/25/88	11.8	7.4	ND	297	0.6	4.630	541.426	ND	ND	0.00	2.350	0.000	9	0.002
M5_53	08/22/88	12.0	8.9	ND	72	1.1	4.984	541.072	ND	ND	0.38	2.454	0.000	10	0.000
M5_53	09/19/88	11.3	7.8	ND	102	0.8	5.258	540.798 ?	ND	ND	0.75 ?	2.471	0.037	6	0.000
M5_53	10/17/88	9.5	7.9	ND	270	1.8	5.474	540.582	ND	ND	0.04	2.178	0.002	10	0.000
M5_53	11/14/88	8.2	8.7	ND	203	2.8	5.517	540.539	ND	ND	0.11	2.470	0.051	13	0.000
M5_53	01/09/89	10.5	7.9	ND	113	1.2	5.486	540.569	ND	ND	0.00	2.536	0.018	10	0.000
M5_53	03/06/89	ND	ND	ND	ND	ND	5.392	540.664	ND	ND	ND	ND	ND	ND	ND
M5_53	04/10/89	9.7	9.3	805	54	-0.0	3.941	542.115	ND	ND	0.14	2.418	0.042	8	0.000
M5_53	05/22/89	9.5	8.8	787	73	0.3	3.524	542.532	ND	ND	0.56	3.610	0.062	12	0.000
M5_53	06/06/89	ND	ND	ND	ND	ND	3.655	542.401	ND	ND	ND	ND	ND	ND	ND
M5_53	06/27/89	ND	ND	ND	ND	ND	3.816	542.240	ND	ND	ND	ND	ND	ND	ND
M5_53	08/21/89	12.7	7.9	944	195	0.4	4.691	541.365	ND	ND	0.56	1.850	0.015	17	0.010
M5_53	10/30/89	9.5	8.7	798	125	0.1	5.410	540.646	ND	ND	1.54	2.250	0.062	11	0.000
M5_53	03/12/90	9.5	8.7	805	137	0.0	4.977	541.078	ND	ND	1.03	1.930	0.168	10	0.010
M5_53	04/30/90	11.4	8.7	565	ND	ND	4.328	541.728	ND	ND	0.89	2.030	0.064	11	0.000
M5_53	06/18/90	13.5	ND	612	ND	3.3	4.237	541.819	ND	ND	ND	ND	ND	ND	ND
M5_53	03/11/91	8.5	8.2	616	ND	2.3	5.008	541.048	ND	128.1	0.00	2.220	0.122	11	0.000
	Wells in the vadose or saturated zones of the tailings														
B1-4	12/09/87	1.0	4.2	ND	ND	ND	ND	ND	-1.8	ND	5	ND	ND	150	0.01
B1-4	02/08/88	3.0	3.9	ND	ND	ND	ND	ND	-1.6	ND	12	ND	ND	130	0.02
B1-4	03/14/88	5.0	4.4	ND	ND	ND	ND	ND	-1.2	ND	9	1.100 ?	0.019	150	0.01
B1-4	04/04/88	7.0	3.8	ND	ND	ND	ND	ND	-0.9	ND	190	0.430	0.010	26	0.02
B1-4	04/18/88	9.0	3.9	ND	ND	ND	ND	ND	-0.7	ND	110	0.260	0.001	180	0.02
B1-4	05/09/88	10.0	3.8	ND	560	ND	ND	ND	-0.8	ND	87	0.400	0.021	150	0.01
B1-4	06/20/88	10.0	3.8	ND	580	3.5	ND	ND	-1.0	ND	130	0.400	0.037	260	0.02
B1-4	07/25/88	13.0	3.9	ND	520	ND	ND	ND	-1.1	ND	61	0.500	0.010	98	0.08 ?
B1-4	08/22/88	17.0	3.8	ND	560	3.5	ND	ND	-1.5	ND	65	0.450	0.010	120	0.01
B1-4	09/19/88	16.0	3.6	ND	530	1.3	ND	ND	-1.6	ND	57	0.370	0.010	120	0.01
B1-4	11/14/88	6.0	3.6	ND	560	0.8	ND	ND	-2.1	ND	60	0.210	0.041	130	0.01
B1-4	01/09/89	4.0	3.5	ND	560	ND	ND	ND	ND	ND	45	0.250	0.010	100	0.01
B1-4	04/11/89	4.0	3.7	ND	430	1.0	ND	ND	-0.2	ND	44	0.045	0.018	43	0.01
B1-4	06/06/89	10.0	ND	ND	ND	ND	ND	ND	-1.5	ND	15	0.01	0.023	22	0.01
B1-4	08/21/89	17.0	4.0	ND	540	0.7	ND	ND	-1.3	ND	24	0.01	0.010	32	0.02
B1-4	10/29/89	9.0	3.9	ND	570	1.6	ND	ND	-1.3	ND	21	0.160	0.017	35	0.01
B1-4	03/12/90	3.0	3.1	ND	550	0.7	ND	ND	-0.3	ND	70	0.120	0.017	60	0.03
B1-4	04/30/90	9.0	3.1	ND	560	ND	ND	ND	-1.0	ND	65	0.130	0.008	63	0.03
B1-7	12/09/87	6.0	4.1	ND	ND	ND	ND	ND	-1.5	ND	22	ND	ND	480	0.04
B1-7	02/08/88	6.0	3.8	ND	ND	ND	ND	ND	-1.4	ND	27	ND	ND	380	0.05
B1-7	03/14/88	5.0	4.2	ND	ND	ND	ND	ND	-1.5	ND	31	0.350	0.012	510	0.04
B1-7	04/04/88	5.0	3.8	ND	ND	ND	ND	ND	ND	ND	240	1.600	0.010	440	0.16

Well ID	Date Sampled	Water Temp (C)	pH	Fld. Cond (uS/cm)	Eh f(mV,Temp)	Diss O2 (ppm)	DTW (m)	Pz El (m)	Neg head (m)	HCO3 (mg/l)	Al (mg/l)	B (mg/l)	Ba (mg/l)	Ca (mg/l)	Cd (mg/l)
B1-7	04/18/88	6.0	3.8	ND	ND	ND	ND	ND	-0.9	ND	340	2.000	0.010	370	0.20
B1-7	05/09/88	7.0	3.7	ND	540	ND	ND	ND	-0.8	ND	590	1.600	0.022	520	0.21
B1-7	06/20/88	8.0	3.9	ND	550	ND	ND	ND	-1.0	ND	830	2.000	0.010	490	0.30
B1-7	07/25/88	10.0	3.6	ND	530	ND	ND	ND	-1.0	ND	670	5.500	0.010	360	0.32
B1-7	08/22/88	12.0	3.7	ND	530	2.1	ND	ND	-1.3	ND	620	3.600	0.010	420	0.29
B1-7	09/19/88	14.0	3.6	ND	530	1.9	ND	ND	-1.4	ND	650	3.900	0.010	490	0.22
B1-7	11/14/88	15.0	3.9	ND	540	2.8	ND	ND	-1.5	ND	620	1.500	0.110	550	0.26
B1-7	01/09/89	7.0	3.6	ND	560	2.0	ND	ND	ND	ND	400	1.200	0.010	430	0.14
B1-7	03/06/89	5.0	3.5	ND	570	1.9	ND	ND	ND	ND	440	1.300	0.010	510	0.17
B1-7	04/11/89	5.0	3.6	ND	500	1.5	ND	ND	-0.7	ND	370	0.880	0.012	400	0.07
B1-7	06/06/89	8.0		ND	ND	ND	ND	ND	-0.9	ND	500	0.990	0.011	460	0.16
B1-7	08/21/89	14.0	3.8	ND	510	0.7	ND	ND	-1.1	ND	940	2.000	0.010	450	0.34
B1-7	10/29/89	12.0		ND	550	ND	ND	ND	-1.4	ND	780	2.100	0.025	430	0.29
B1-7	03/12/90	6.0	3.6	ND	540	0.3	ND	ND	-1.5	ND	620	2.500	0.100	670	0.29
B1-7	04/30/90	9.0	3.2	ND	540	ND	ND	ND	ND	ND	120	2.600	0.010	450	0.16
B1-16	12/09/87	9.0	3.4	ND	ND	ND	ND	ND	ND	ND	1900	ND	ND	400	14.00
B1-16	02/08/88	9.0	3.4	ND	ND	ND	ND	563.000	1.3	ND	2400	ND	ND	340	17.00
B1-16	03/14/88	9.0	3.5	ND	ND	ND	ND	562.900	1.2	ND	1600	17	0.005	320	14.00
B1-16	04/04/88	8.0	3.5	ND	ND	ND	ND	563.000	1.3	ND	2500	25	0.010	450	21.00
B1-16	04/18/88	8.0	3.4	ND	ND	ND	ND	563.300	1.6	ND	2200	30	0.014	460	18.00
B1-16	05/09/88	8.0	3.5	ND	480	ND	ND	563.400	1.7	ND	2500	24	0.038	550	19.00
B1-16	06/20/88	8.0	3.7	ND	510	2.3	ND	563.500	1.8	ND	2200	21	0.010	460	18.00
B1-16	07/25/88	8.0	3.6	ND	520	ND	ND	563.500	1.8	ND	2500	61	0.010	310	26.00
B1-16	08/22/88	9.0	3.6	ND	500	2.5	ND	563.300	1.6	ND	1800	42	0.010	330	17.00
B1-16	09/19/88	10.0	3.5	ND	480	2.2	ND	563.200	1.5	ND	2300	26	0.010	2000 ?	6.30
B1-16	11/14/88	6.0	3.5	ND	480	2.1	ND	563.000	1.3	ND	3700	33	0.300 ?	880	26.00
B1-16	01/09/89	9.0	3.5	ND	510	2.5	ND	ND	ND	ND	2400	28	0.010	550	18.00
B1-16	03/06/89	9.0	3.3	ND	540	1.5	ND	ND	ND	ND	2700	29	0.010	690	20.00
B1-16	04/11/89	8.0	3.3	ND	ND	1.6	ND	562.800	1.1	ND	4700	44	0.011	1000	33.00
B1-16	06/06/89	8.0	ND	ND	ND	ND	ND	563.300	1.6	ND	160	0.010 ?	0.010	500	1.90
B1-16	08/21/89	10.0	3.6	ND	460	0.4	ND	563.300	1.6	ND	2100	16	0.010	450	14.00
B1-16	10/29/89	11.0	3.7	ND	510	0.8	ND	563.100	1.4	ND	1700	21	0.036	410	12.00
B1-16	03/12/90	12.0	ND	ND	ND	ND	ND	562.700	1.0	ND	1700	32	0.035	410	11.00
B1-16	04/30/90	9.0	3.5	ND	450	ND	ND	562.400	0.7	ND	2000	35	0.010	480	12.00
B2-4	12/09/87	4.0	3.2	ND	ND	ND	ND	ND	-2.0	ND	690	ND	ND	400	0.95
B2-4	02/08/88	2.0	3.1	ND	ND	ND	ND	ND	-1.8	ND	1100	ND	ND	320	1.10
B2-4	03/14/88	2.0	3.4	ND	ND.	ND	ND	ND	-1.1	ND	850	50.0 ?	0.013	370	0.85
B2-4	04/04/88	3.0	3.3	ND	ND	ND	ND	ND	-0.7	ND	810	5.7	0.010	440	1.30
B2-4	04/18/88	5.0	2.8	ND	ND	ND	ND	ND	-1.0	ND	920	8.6	0.010	420	1.70
B2-4	05/09/88	8.0	2.8	ND	650	ND	ND	ND	ND	ND	1200	7.4	0.010	480	2.50
B2-4	06/20/88	11.0	3.1	ND	610	3.4	ND	ND	-1.3	ND	850	4.4	0.027	450	1.50
B2-4	07/25/88	15.0	3.1	ND	590	ND	ND	ND	-1.4	ND	770	16.0	0.010	470	1.90
B2-4	08/22/88	18.0	3.0	ND	560	2.3	ND	ND	-1.6	ND	370	6.4	0.010	320	0.92
B2-4	09/19/88	18.0	3.0	ND	550	0.9	ND	ND	-1.8	ND	1500	35.0	0.010	320	12.00 ?
B2-4	11/14/88	10.0	3.3	ND	570	0.9	ND	ND	-2.1	ND	470	3.5	0.010	620 ?	0.92

Well ID	Date Sampled	Water Temp (C)	pH	Fld. Cond (uS/cm)	Eh f(mV,Temp)	Diss O2 (ppm)	DTW (m)	Pz El (m)	Neg head (m)	HCO3 (mg/l)	Al (mg/l)	B (mg/l)	Ba (mg/l)	Ca (mg/l)	Cd (mg/l)
B2-4	01/09/89	4.0	3.2	ND	550	1.1	ND	ND	ND	ND	320	3.1	0.010	380	0.65
B2-4	03/06/89	3.0	3.3	ND	580	2.1	ND	ND	ND	ND	330	3.0	0.010	440	0.68
B2-4	04/11/89	4.0	3.3	ND	ND	0.6	ND	ND	-0.8	ND	410	2.6	0.010	390	0.54
B2-4	06/06/89	11.0	ND	ND	ND	ND	ND	ND	-1.1	ND	370	2.2	0.010	450	0.35
B2-4	08/21/89	18.0	3.4	ND	510	0.2	ND	ND	-1.6	ND	350	2.7	0.010	390	0.46
B2-4	10/29/89	10.0	3.5	ND	560	2.3	ND	ND	-1.1	ND	310	2.9	0.025	430	0.42
B2-4	03/12/90	2.0	2.8	ND	530	0.3	ND	ND	-0.3	ND	420	5.3	0.025	400	0.48
B2-4	04/30/90	9.0	3.3	ND	480	ND	ND	ND	ND	ND	380	5.3	0.010	340	0.43
B2-8	12/09/87	8.0	4.0	ND	ND	ND	ND	ND	ND	ND	65	ND	ND	480	0.34
B2-8	02/08/88	7.0	3.8	ND	ND	ND	ND	ND	ND	ND	140	ND	ND	430	0.56
B2-8	03/14/88	6.0	4.0	ND	ND	ND	ND	ND	-1.7	ND	95	0.8	0.013	440	0.42
B2-8	04/04/88	4.0	4.0	ND	ND	ND	ND	ND	-1.8	ND	99	0.8	0.010	470	0.47
B2-8	04/18/88	5.0	4.0	ND	ND	ND	ND	ND	-1.3	ND	170	1.6	0.010	510	0.65
B2-8	05/09/88	6.0	4.0	ND	520	ND	ND	ND	-1.0	ND	250	1.9	0.018	520	0.96
B2-8	06/20/88	7.0	4.1	ND	530	4.1	ND	ND	-1.1	ND	290	1.9	0.010	410	1.10
B2-8	07/25/88	8.0	3.9	ND	520	ND	ND	ND	-1.1	ND	310	5.5	0.010	280 ?	1.20
B2-8	09/19/88	14.0	3.7	ND	510	1.3	ND	ND	-1.5	ND	140	3.2	0.010	510	0.85
B2-8	11/14/88	12.0	3.5	ND	510	0.7	ND	ND	ND	ND	650	2.4	0.150 ?	510	1.50
B2-8	01/09/89	8.0	3.5	ND	540	1.1	ND	ND	ND	ND	670	2.9	0.010	460	1.40
B2-8	03/06/89	6.0	3.4	ND	560	1.9	ND	ND	ND	ND	660	2.8	0.010	450	1.40
B2-8	04/11/89	4.0	3.6	ND	480	0.7	ND	ND	-0.8	ND	660	2.4	0.010	440	1.40
B2-8	08/21/89	8.0	3.8	ND	520	1.2	ND	ND	-0.5	ND	800	3.5	0.010	460	1.80
B2-8	10/29/89	12.0	3.8	ND	520	ND	ND	ND	-0.3	ND	760	2.8	0.018	450	1.60
B2-8	03/12/90	5.0	3.0	ND	540	0.9	ND	ND	-0.2	ND	780	5.4	0.022	430	1.60
B2-8	04/30/90	8.0	3.4	ND	490	ND	ND	ND	-0.5	ND	780	5.9	0.010	420	1.50
B2-16	12/09/87	10.0	3.9	ND	ND	ND	ND	ND	ND	ND	90	ND	ND	480	0.37
B2-16	02/08/88	10.0	3.8	ND	ND	ND	ND	ND	ND	ND	170	ND	ND	390	0.62
B2-16	03/14/88	10.0	3.9	ND	ND	ND	ND	562.200	0.5	ND	130	1.9	0.010	450	0.69
B2-16	04/04/88	9.0	3.9	ND	ND	ND	ND	562.200	0.5	ND	180	2.5	0.010	470	1.30
B2-16	04/18/88	9.0	3.9	ND	ND	ND	ND	562.300	0.6	ND	190	2.7	0.010	480	1.10
B2-16	05/09/88	8.0	3.9	ND	410	ND	ND	562.400	0.7	ND	200	1.9	0.016	540	1.20
B2-16	06/20/88	8.0	4.1	ND	530	4.1	ND	562.600	0.9	ND	170	1.8	0.010	480	1.10
B2-16	07/25/88	9.0	4.0	ND	510	ND	ND	562.700	1.0	ND	140	3.9	0.010	350	1.10
B2-16	09/19/88	10.0	3.9	ND	520	1.8	ND	562.000	0.3	ND	250	5.0	0.010	300	0.59
B2-16	11/14/88	11.0	3.8	ND	520	0.8	ND	561.900	0.2	ND	110	1.0	0.010	480	0.60
B2-16	01/09/89	11.0	3.9	ND	560	2.2	ND	ND	ND	ND	94	1.0	0.010	500	0.57
B2-16	03/06/89	10.0	3.7	ND	560	2.2	ND	ND	ND	ND	100	1.0	0.010	520	0.74
B2-16	04/11/89	9.0	3.8	ND	440	0.5	ND	562.400	0.7	ND	120	1.2	0.003	480	1.10
B2-16	06/06/89	8.0	ND	ND	ND	ND	ND	562.500	0.8	ND	130	1.3	0.003	420	1.60
B2-16	08/21/89	10.0	4.0	ND	490	0.7	ND	562.300	0.6	ND	180	2.2	0.010	480	1.80
B2-16	10/29/89	11.0	4.0	ND	530	1.0	ND	562.000	0.3	ND	120	2.2	0.012	400	1.60
B2-16	03/12/90	9.0	3.3	ND	520	0.2	ND	562.000	0.3	ND	110	2.2	0.020	490	1.20
B2-16	04/30/90	9.0	3.8	ND	450	ND	ND	562.300	0.6	ND	110	2.5	0.010	480	1.20
P4	02/08/88	7.7	4.7	ND	ND	ND	3.898	562.761	ND	ND	30	ND	ND	260	1.60

Well ID	Date Sampled	Water Temp (C)	pH	Fld Cond (uS/cm)	Eh f(mV,Temp)	Diss O2 (ppm)	DTW (m)	Pz El (m)	Neg head (m)	HCO3 (mg/l)	Al (mg/l)	B (mg/l)	Ba (mg/l)	Ca (mg/l)	Cd (mg/l)
P4	03/14/88	9.3	4.6	ND	ND	ND	3.926	562.734	ND	ND	86	10.0	0.027	280	2.60
P4	04/04/88	ND	ND	ND	ND	ND	3.569	563.091	ND	ND	140	16.0	0.010	390	2.50
P4	04/18/88	10.4	4.6	ND	ND	ND	3.402	563.258	ND	ND	82	20.0	0.010	330	2.60
P4	05/09/88	14.3	4.5	ND	430	ND	ND	ND	ND	ND	200 ?	25.0	ND	520	4.80
P4	05/30/88	10.4	4.8	ND	270	ND	3.432	563.228	ND	ND	58	21.0	ND	470	2.10
P4	07/25/88	22.9	4.5	ND	410	1.2	3.575	563.084	ND	ND	77	43.0	0.010	390	2.90
P4	08/22/88	17.8	4.5	ND	390	5.4	3.719	562.941	ND	ND	93	41.0	0.010	370	3.20
P4	10/17/88	10.4	3.8	ND	490	3.0	3.904	562.755	ND	ND	75	18.0	0.010	600	5.20
P4	11/14/88	11.3	5.0	ND	420	5.7	4.005	562.655	ND	ND	69	21.0	0.010	560	2.40
P4	01/09/89	9.0	5.3	ND	290	4.9	4.145	562.514	ND	ND	78	16.0	0.010	520	2.60
P4	03/06/89	7.2	4.9	ND	430	2.5	4.167	562.493	ND	ND	60	16.0	0.010	440	2.00
P4	05/22/89	10.7	4.7	ND	370	1.2	3.557	563.103	ND	ND	87	18.0	0.010	450	2.10
P4	08/21/89	15.0	4.6	ND	420	0.1	3.566	563.094	ND	ND	47	9.1	0.021	620	1.90
P4	10/29/89	7.0	4.8	ND	380	0.7	3.819	562.841	ND	ND	50	23.0	0.012	460	1.10
P4	03/12/90	14.3	4.7	ND	420	5.8	3.978	562.682	ND	ND	37	26.0	0.220 ?	420	1.20
P4	04/30/90	16.9	4.5	ND	400	ND	ND	ND	ND	ND	51	23.0	0.070	430	1.30
P5	02/08/88	10.6	4.0	ND	ND	ND	4.337	562.743	ND	ND	670	ND	ND	230	3.10
P5	03/14/88	11.7	3.9	ND	ND	ND	ND	ND	ND	ND	900	8.7	0.018	300	3.60
P5	04/04/88	ND	ND	ND	ND	ND	4.209	562.871	ND	ND	1100	13.0	0.010	380	3.40
P5	04/18/88	12.7	3.9	ND	ND	ND	4.063	563.017	ND	ND	1100	15.0	0.010	350	3.70
P5	05/09/88	15.2	3.9	ND	500	ND	3.926	563.155	ND	ND	16000 ?	20.0	ND	510	6.30
P5	05/30/88	10.1	3.4	ND	300	ND	3.904	563.176	ND	ND	1600	20.0	ND	520	6.20
P5	07/25/88	22.5	3.5	ND	510	5.5	ND	ND	ND	ND	1200	34.0	0.010	410	6.00
P5	08/22/88	19.1	3.7	ND	520	4.3	4.118	562.963	ND	ND	1100	31.0	0.010	360	5.10
P5	10/17/88	10.1	4.4	ND	410	6.3	4.389	562.691	ND	ND	110	21.0	0.010	570	3.10
P5	11/14/88	12.0	4.2	ND	500	5.2	ND	ND	ND	ND	1400	18.0	0.010	580	5.00
P5	01/09/89	9.1	4.6	ND	490	3.4	4.560	562.521	ND	ND	1100	13.0	0.010	520	3.70
P5	03/06/89	8.8	4.1	ND	540	1.7	4.612	562.469	ND	ND	900	14.0	0.010	440	3.40
P5	05/22/89	10.4	3.9	ND	450	1.0	4.023	563.057	ND	ND	1000	16.0	0.010	470	4.60
P5	08/21/89	14.5	3.9	ND	520	0.0	4.002	563.078	ND	ND	830	19.0	0.150	270	10.00
P5	10/29/89	7.2	4.1	ND	490	0.6	4.267	562.813	ND	ND	720	19.0	0.018	460	3.60
P5	03/12/90	11.6	3.8	ND	500	4.4	4.417	562.664	ND	ND	900	28.0	0.190	530	3.90
P5	04/30/90	18.6	6.4	ND	360	ND	ND	ND	ND	ND	1200	19.0	0.100	440	2.50
P6	02/08/88	7.9	4.9	ND	ND	ND	3.798	562.905	ND	ND	2	ND	ND	260	0.01
P6	03/14/88	13.4	4.6	ND	ND	ND	3.633	563.069	ND	ND	1	21.0	0.012	290	0.01
P6	04/04/88	ND	ND	ND	ND	ND	3.429	563.273	ND	ND	1	32.0	0.013	350	0.01
P6	04/18/88	12.2	5.1	ND	ND	ND	3.167	563.536	ND	ND	4	36.0	0.010	330	0.01
P6	05/09/88	15.3	5.0	ND	330	ND	3.252	563.450	ND	ND	5	64.0	ND	580	0.01
P6	05/30/88	11.1	5.0	ND	250	ND	3.298	563.405	ND	ND	1	63.0	ND	580	0.01
P6	06/20/88	20.1	4.5	ND	570	ND	3.316	563.386	ND	ND	0	62.0	ND	570	0.01
P6	07/25/88	24.6	4.2	ND	410	2.9	3.475	563.228	ND	ND	15	120.0	0.010	450	0.01
P6	08/22/88	20.8	4.7	ND	370	2.6	3.606	563.097	ND	ND	10	120.0	0.010	440	0.01
P6	10/17/88	11.2	4.6	ND	330	4.7	3.819	562.883	ND	ND	2	56.0	0.010	640	0.01
P6	11/14/88	11.8	4.8	ND	430	3.7	4.234	562.469	ND	ND	4	59.0	0.010	630	0.04
P6	01/09/89	7.9	5.1	ND	400	3.5	4.057	562.646	ND	ND	0	50.0	0.010	870	0.01

Well ID	Date Sampled	Water Temp (C)	pH	Fld. Cond (uS/cm)	Eh f(mV,Temp)	Diss O2 (ppm)	DTW (m)	Pz El (m)	Neg head (m)	HCO3 (mg/l)	Al (mg/l)	B (mg/l)	Ba (mg/l)	Ca (mg/l)	Cd (mg/l)
P6	03/06/89	9.0	4.4	ND	450	1.4	4.042	562.661	ND	ND	48	47.0	0.010	490	0.33
P6	05/22/89	12.2	4.3	ND	420	3.4	3.219	563.484	ND	ND	20	60.0	0.010	610	0.01
P6	08/21/89	17.9	4.3	ND	450	0.1	3.475	563.228	ND	ND	28	29.0	0.045	700	0.23
P6	10/29/89	11.6	5.4	ND	320	0.2	3.795	562.908	ND	ND	80	82.0	0.077	630	0.01
P6	03/12/90	9.7	4.3	ND	440	1.3	3.813	562.889	ND	ND	52	97.0	0.500 ?	550	0.87 ?
P6	04/30/90	15.6	4.5	ND	390	ND	ND	ND	ND	ND	44	94.0	0.170	670	0.01
		Wells at the base of or below the tailings													
P1	02/08/88	ND	ND	ND	ND	ND	5.422	561.979	ND	ND	0.00	ND	ND	350	0.000
P1	03/14/88	12.9	6.4	ND	ND	ND	5.334	562.067	ND	ND	0.08	2.80	0.056	530	0.000
P1	04/04/88	8.6	6.4	ND	ND	ND	5.099	562.302	ND	ND	0.00	0.79	0.047	600	0.001
P1	04/18/88	14.2	6.1	ND	ND	ND	5.005	562.396	ND	ND	0.00	0.67	0.025	88	0.004
P1	05/09/88	14.8	6.2	ND	224	ND	4.956	562.445	ND	ND	0.00	1.22	0.000	453	0.008
P1	05/30/88	10.6	6.3	ND	226	ND	5.002	562.399	ND	ND	0.00	1.01	0.025	661	0.000
P1	06/20/88	15.1	6.5	ND	190	2.0	4.984	562.418	ND	ND	0.13	1.10	0.069	678	0.000
P1	04/10/89	8.2	6.7	3070	130	0.8	5.083	562.319	ND	ND	0.31	0.36	0.039	658	0.000
P1	05/22/89	10.9	6.4	7045	190	1.4	4.892	562.509	ND	ND	0.51	1.38	0.098	509	0.000
P1	06/06/89	ND	ND	ND	ND	ND	4.862	562.540	ND	ND	ND	ND	ND	ND	ND
P1	06/27/89	ND	ND	ND	ND	ND	4.862	562.540	ND	ND	ND	ND	ND	ND	ND
P1	04/30/90	18.9	6.7	ND	266	0.3	5.087	562.314	ND	ND	0.99	0.36	0.031	630	0.000
P1	06/10/90	24.2	6.3	ND	ND	ND	4.977	562.424	ND	ND	0.51	0.56	0.088	635	0.000
P2	02/08/88	8.5	6.6	ND	ND	ND	5.182	562.048	ND	ND	0.010	ND	ND	190	0.01
P2	03/14/88	10.0	7.0	ND	ND	ND	5.105	562.124	ND	ND	0.010	0.400	0.090	260	0.02
P2	04/04/88	10.0	7.0	ND	ND	ND	4.855	562.374	ND	ND	0.040	0.320	0.770	280	0.01
P2	04/18/88	16.4	6.6	ND	ND	ND	4.788	562.441	ND	ND	0.010	0.210	0.046	250	0.01
P2	05/09/88	10.8	6.9	ND	140	ND	4.752	562.478	ND	ND	0.250	0.250	0.059	290	0.02
P2	05/30/88	10.8	6.9	ND	220	ND	4.828	562.402	ND	ND	0.040	0.240	0.051	280	0.01
P2	06/20/88	15.3	6.8	ND	250	0.7	4.825	562.405	ND	ND	0.140	0.270	0.072	280	0.02
P2	07/25/88	22.6	6.5	ND	150	5.4	5.093	562.137	ND	ND	0.010	0.240	0.027	280	0.01
P2	08/22/88	22.1	5.1	ND	150	2.7	5.255	561.975	ND	ND	0.440	0.380	0.010	320	0.20
P2	10/17/88	10.4	6.4	ND	330	6.0	5.425	561.804	ND	ND	0.130	0.380	0.047	420	0.32
P2	11/14/88	9.8	6.6	ND	300	4.9	5.395	561.835	ND	ND	1.300	0.540	0.038	420	0.54 ?
P2	01/09/89	8.0	6.8	ND	220	3.4	5.517	561.713	ND	ND	0.010	1.600	0.070	390	0.03
P2	03/06/89	7.7	6.6	ND	190	8.3	5.502	561.728	ND	ND	0.450	0.470	0.085	400	0.02
P2	04/11/89	ND	6.9	2452	ND	0.4	4.907	562.322	ND	ND	0.150	0.230	0.077	390	0.02
P2	05/22/89	10.8	6.7	3592	130	1.3	4.700	562.530	ND	ND	0.270	0.350	0.110	350	0.01
P2	08/21/89	14.3	5.2	4920	420	0.4	5.090	562.140	ND	ND	43.000	0.700	0.075	370	6.10 ?
P2	10/29/89	7.7	6.0	3727	310	1.3	5.236	561.993	ND	ND	5.100	0.710	0.069	350	1.90 ?
P2	03/12/90	12.7	6.4	ND	220	1.3	5.182	562.048	ND	ND	1.400	0.410	0.290	370	0.19
P2	04/30/90	16.6	6.6	ND	240	ND	ND	ND	ND	ND	0.890	0.270	0.090	310	0.04
P3	02/08/88	7.9	7.0	ND	ND	ND	4.572	562.383	ND	ND	0.010	ND	ND	350	0.01
P3	03/14/88	9.4	7.0	ND	ND	ND	4.471	562.484	ND	ND	0.010	0.440	0.085	350	0.05
P3	04/04/88	15.1	7.1	ND	ND	ND	4.225	562.731	ND	ND	0.070	0.280	0.120	380	0.02

Well ID	Date Sampled	Water Temp (C)	pH	Fld. Cond (uS/cm)	Eh f(mV,Temp)	Diss O2 (ppm)	DTW (m)	Pz El (m)	Neg head (m)	HCO3 (mg/l)	Al (mg/l)	B (mg/l)	Ba (mg/l)	Ca (mg/l)	Cd (mg/l)
P3	04/18/88	14.8	6.7	ND	ND	ND	4.185	562.771	ND	ND	0.210	0.310	0.045	370	0.01
P3	05/09/88	15.2	7.0	ND	200	ND	ND	ND	ND	ND	0.350	0.310	0.045	400	0.03
P3	05/30/88	ND	ND	ND	ND	ND	4.127	562.828	ND	ND	0.500	0.330	0.120	420	0.02
P3	06/20/88	23.1	6.7	ND	430	5.8	4.103	562.853	ND	ND	0.210	0.360	0.063	450	0.02
P3	07/25/88	29.8	6.9	ND	200	4.8	4.374	562.582	ND	ND	0.010	0.430	0.055	350	0.03
P3	08/22/88	18.2	7.2	ND	150	2.7	4.584	562.371	ND	ND	0.380	0.290	0.010	320	0.02
P3	10/17/88	10.0	6.8	ND	320	5.6	4.788	562.167	ND	ND	0.250	0.290	0.037	490	0.01
P3	11/14/88	10.2	7.1	ND	190	2.0	5.060	561.896	ND	ND	0.120	0.370	0.042	440	0.02
P3	01/09/89	8.3	6.5	ND	260	6.3	4.868	562.088	ND	ND	0.010	0.280	0.046	410	0.01
P3	03/06/89	8.9	6.6	ND	210	4.1	4.852	562.103	ND	ND	0.400	0.290	0.080	400	0.02
P3	04/11/89	ND	7.2	3340	110	12.0	4.243	562.713	ND	ND	0.160	0.220	0.080	320	0.01
P3	05/22/89	10.5	6.9	3148	160	0.8	3.993	562.963	ND	ND	1.200	0.280	0.089	380	0.02
P3	08/21/89	14.7	6.9	3126	230	0.4	4.353	562.603	ND	ND	0.520	0.330	0.054	270	0.01
P3	10/29/89	6.6	7.2	3004	170	0.7	4.505	562.450	ND	ND	1.700	0.230	0.066	370	0.02
P3	03/12/90	15.0	6.9	ND	190	4.7	4.505	562.450	ND	580	1.100	0.240	0.340	380	0.03
P3	04/30/90	18.3	6.9	ND	250	ND	ND	ND	ND	ND	0.910	ND	ND	370	ND
P3A	06/18/90	19.2	6.6	ND	ND	ND	4.161	ND	ND	ND	0.450	0.580	0.092	474	0.00
P3A	03/11/91	11.3	6.5	3361	196	5.0	4.648	562.229	ND	661	1.620	0.660	0.079	689	0.00
P3A	06/03/91	11.9	6.3	3660	289	ND	4.508	562.369	ND	647	0.410	0.570	0.084	480	0.01
P3A	03/30/92	13.5	6.4	2100	227	ND	4.657	562.220	ND	714	0.110	0.590	0.032	419	0.01
P3A	05/26/92	18.1	6.3	1831	187	ND	4.627	562.250	ND	ND	0.390	0.710	0.081	410	0.01
P3A	08/26/92	26.5	6.3	ND	176	ND	ND	ND	ND	ND	0.440	1.040	0.032	574	0.00
P3A	11/17/92	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.000	1.300	0.090	550	0.20
P3A	03/01/93	10.5	6.4	1867	231	2.5	5.197	561.680	ND	ND	0.000	1.260	0.041	559	0.13
P3B	06/18/90	17.7	6.3	ND	ND	ND	4.167	562.802	ND	ND	0.440	1.800	0.086	546	0.00
P3B	03/11/91	12.5	6.4	5900	209	2.9	4.636	562.332	ND	542	1.770	2.890	0.091	542	0.01
P3B	06/03/91	14.3	6.0	3460	266	ND	4.499	562.470	ND	455	0.360	2.710	0.018	549	0.01
P3B	03/30/92	16.8	6.0	3100	248	ND	4.685	562.284	ND	423	2.610	2.060	0.009	522	0.01
P3B	05/26/92	17.1	6.0	3310	230	ND	4.633	562.335	ND	ND	0.000	2.830	0.031	515	0.00
P3B	08/26/92	26.8	5.9	ND	196	ND	5.023	561.945	ND	ND	2.320	3.020	0.023	543	0.00
P3B	11/17/92	ND	ND	ND	ND	ND	ND	ND	ND	ND	2.800	4.300	0.090	514	0.20
P3B	03/01/93	13.0	5.9	3335	262	1.6	5.169	561.799	ND	ND	1.680	4.100	0.025	573	0.06
P3C	06/18/90	18.4	6.9	ND	ND	ND	4.188	562.793	ND	ND	0.420	0.230	0.118	341	0.01
P3C	03/11/91	9.1	6.8	2722	174	1.9	4.663	562.317	ND	577	0.580	0.380	0.049	270	0.00
P3C	06/03/91	17.0	6.5	1410	240	ND	4.532	562.448	ND	573	0.360	0.520	0.058	391	0.02
P3C	03/30/92	14.6	6.6	1400	205	ND	4.679	562.302	ND	573	0.150	0.600	0.061	376	0.01
P3C	05/26/92	17.1	6.6	1224	153	ND	4.673	562.308	ND	ND	0.000	0.570	0.071	370	0.01
P3C	08/26/92	19.8	6.4	2300	133	ND	5.127	561.854	ND	ND	0.490	1.060	0.100	600	0.01
P3C	11/17/92	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.000	1.200	0.160	586	0.20
P3C	03/01/93	9.3	6.7	1369	184	0.9	5.237	561.744	ND	ND	0.000	1.130	0.097	522	0.00

Well ID	Date Sampled	Cl (mg/l)	Cu (mg/l)	Fe (mg/l)	K (mg/l)	Mg (mg/l)	Mn (mg/l)	Na (mg/l)	Ni (mg/l)	Pb (mg/l)	S (mg/l)	SO4 (mg/l)	Si (mg/l)	Zn (mg/l)
		Background and downgradient wells												
BKG_6	02/08/88	ND	0.00	2.40	2.10	24.0	0.140 ?	20.0	ND	0.00	77	ND	ND	0.47
BKG_6	03/14/88	ND	0.00	0.00	2.40	26.0	0.000	20.0	0.00	0.01	70	ND	12.0	0.01
BKG_6	04/04/88	ND	0.10	0.22	2.60	40.0	0.007	21.0	0.01	0.11	130	ND	19.0	0.04
BKG_6	04/18/88	ND	0.00	0.07	2.20	28.0	0.000	20.0	0.00	0.01	68	ND	12.0	0.00
BKG_6	05/09/88	ND	0.00	0.00	2.50	26.8	0.026	18.8	0.00	0.00	81	ND	12.9	0.03
BKG_6	05/30/88	ND	0.02	0.00	2.53	30.2	0.033	20.8	0.00	0.00	84	ND	14.0	0.05
BKG_6	06/20/88	ND	0.10	0.53	2.50	29.1	0.014	23.1	0.01	0.00	80	ND	14.0	0.02
BKG_6	07/25/88	ND	0.00	0.50	2.56	26.5	0.001	18.8	0.00	0.00	80	239	11.2	0.01
BKG_6	08/22/88	ND	0.04	0.09	1.93	29.7	0.000	15.5	0.00	0.09	252 ?	244	13.7	0.03
BKG_6	09/19/88	ND	0.17 ?	0.16	2.43	28.2	0.122 ?	19.1	0.00	0.08	90	246	12.2	0.12
BKG_6	10/17/88	ND	0.01	4.02	2.70	29.0	0.023	22.6	0.00	0.05	97	247	13.3	0.33
BKG_6	11/14/88	ND	0.04	1.90	3.40	31.7	0.019	26.0	0.01	0.06	97	249	15.1	0.21
BKG_6	01/09/89	ND	0.02	0.31	2.70	28.0	0.037	19.8	0.00	0.00	85	253	12.9	0.01
BKG_6	03/06/89	ND	0.06	1.99	2.10	25.2	0.014	19.1	0.00	0.10	69	236	12.9	0.15
BKG_6	04/10/89	ND	0.00	0.58	2.30	24.7	0.008	17.8	0.00	0.04	71	218	11.2	0.14
BKG_6	05/22/89	ND	0.07	1.22	1.20	270.4	1.229	56.3	0.00	0.00	551	185	20.3	0.08
BKG_6	06/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BKG_6	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BKG_6	08/21/89	ND	0.23	0.79	1.90	53.1	0.049	13.1	0.00	0.07	88	199	17.8	0.11
BKG_6	10/30/89	4.83	0.08	0.05	1.90	26.5	0.002	21.3	0.00	0.21	78	216	10.8	0.17
BKG_6	04/30/90	5.22	0.07	0.35	2.20	24.1	0.013	21.7	0.01	0.08	67	194	14.4	0.17
BKG_6	06/18/90	5.18	0.07	0.60	2.40	25.8	0.003	23.8	0.00	0.01	84	216	13.0	0.11
BKG_6	03/11/91	3.35	7.23	10.56	0.70	21.7	0.399	19.0	0.01	0.00	96	196	12.1	1.32
BKG_6	06/03/91	3.39	0.09	2.79	1.30	22.7	0.014	19.9	0.02	0.08	68	196	10.3	0.27
BKG_20	02/08/88	ND	0.00	0.00	1.70	21.0	0.230	140.0	ND	0.00	88	ND	ND	0.00
BKG_20	03/14/88	ND	0.04	0.34	2.50	23.0	0.170	190.0	0.00	0.00	90	ND	9.6	0.02
BKG_20	04/04/88	ND	0.01	0.34	2.30	25.0	0.150	180.0	0.00	0.03	100	ND	10.0	0.02
BKG_20	04/18/88	ND	0.04	1.00	1.70	24.0	0.092	140.0	0.00	0.00	93	ND	8.5	0.00
BKG_20	05/09/88	ND	0.00	0.06	2.58	24.9	0.127	177.3	0.00	0.00	104	ND	10.3	0.01
BKG_20	05/30/88	ND	0.00	0.60	2.18	32.6	0.151	175.9	0.00	0.00	127	ND	11.3	0.05
BKG_20	06/20/88	ND	0.00	0.84	2.55	28.9	0.206	196.2	0.00	0.00	101	ND	11.2	0.03
BKG_20	07/25/88	ND	0.00	0.00	2.73	29.3	0.114	184.1	0.00	0.00	120	357	11.2	0.00
BKG_20	08/22/88	ND	0.04	2.92	2.24	27.0	0.234	169.2	0.00	0.03	375	332	10.7	0.44
BKG_20	09/19/88	ND	0.10 ?	0.61	2.70	25.2	0.107	183.8	0.01	0.10	118	307	10.3	0.11
BKG_20	10/17/88	ND	0.01	2.09	2.70	27.0	0.095	238.5	0.00	0.00	117	308	11.4	0.15
BKG_20	11/14/88	ND	0.06	4.03	3.50	26.0	0.136	228.2	0.01	0.07	115	313	11.4	0.12
BKG_20	01/09/89	ND	0.01	0.70	3.00	26.4	0.104	209.3	0.00	0.01	112	315	11.0	0.06
BKG_20	03/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BKG_20	04/10/89	ND	0.00	0.53	2.40	22.9	0.086	159.5	0.00	0.12	98	291	9.5	0.04
BKG_20	05/22/89	ND	0.18	2.24	1.50	41.6	0.207	143.9	0.00	0.03	178	281	16.9	0.31
BKG_20	06/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BKG_20	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BKG_20	08/21/89	ND	0.16	0.83	1.90	46.0	0.280	130.8	0.00	0.00	111	277	13.4	0.08
BKG_20	10/30/89	4.30	0.11	0.29	1.60	21.7	0.087	171.0	0.00	0.14	100	303	8.2	0.14

Well ID	Date Sampled	Cl (mg/l)	Cu (mg/l)	Fe (mg/l)	K (mg/l)	Mg (mg/l)	Mn (mg/l)	Na (mg/l)	Ni (mg/l)	Pb (mg/l)	S (mg/l)	SO4 (mg/l)	Si (mg/l)	Zn (mg/l)
BKG_20	04/30/90	4.97	0.03	0.62	2.10	22.5	0.092	171.8	0.01	0.09	101	299	11.3	0.06
BKG_20	06/18/90	2 81	0.06	0.13	2.00	25.2	0.104	198.9	0.00	0.01	120	329	10.3	0.08
BKG_20	03/11/91	2.23	0.03	0.34	1.50	22.2	0.094	206.5	0.01	0.00	105	305	9.6	0.00
BKG_43	02/08/88	ND	0.00	0.00	1.80	13.0	0.008	150.0	ND	0.00	81	ND	ND	0.00
BKG_43	03/14/88	ND	0.00	0.07	2.40	15.0	0.012	200.0	0.00	0.02	86	400 ?	7.8	0.00
BKG_43	04/04/88	ND	0.06	0.30	2.60	25.0	0.039	220.0	0.01	0.12	150	ND	13.0	0.03
BKG_43	04/18/88	ND	0.00	0.00	2.00	16.0	0.000	200.0	0.00	0.01	95	ND	8.3	0.00
BKG_43	05/09/88	ND	0.03	0.00	2.53	16.8	0.036	207.0	0.00	0.00	106	ND	9.0	0.07
BKG_43	05/30/88	ND	0.00	0.97	2.12	19.7	0.063	187.5	0.00	0.00	131	ND	9.5	0.10
BKG_43	06/20/88	ND	0.00	0 69	2.78	19.6	0.022	245.1	0.00	0.00	110	ND	10.2	0.00
BKG_43	07/25/88	ND	0.09	0.87	2.41	29.7	0.045	154.9	0.00	0.06	207	307	13.9	0.03
BKG_43	08/22/88	ND	0.03	0.38	2.07	20.7	0.000	190.7	0.00	0.03	352	324	9.8	0.08
BKG_43	09/19/88	ND	0.19 ?	0.23	2.57	15.0	0.012	169.1	0.00	0.09	97	306	7.6	0.09
BKG_43	10/17/88	ND	0.00	1.63	3.40	18.9	0.018	267.2	0.00	0.01	125	312	9.9	0.07
BKG_43	11/14/88	ND	0.05	1.72	3.40	20.0	0.028	272.4	0.00	0.09	118	317	10.5	0.09
BKG_43	01/09/89	ND	0.01	4.18 ?	3.10	18.3	0.018	243.9	0.00	0.10	109	318	9.9	0.03
BKG_43	03/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BKG_43	04/10/89	ND	0.00	0.83	2.10	17.1	0.044	184.0	0.00	0.08	106	287	8.8	0.07
BKG_43	05/22/89	ND	0.03	1.39	2.50	18.6	0.032	251.6	0.00	0.07	159	279	10.3	0.13
BKG_43	06/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BKG_43	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
BKG_43	08/21/89	ND	0.11	1.76	3.20	33.0	0.083	245.0	0.00	0.04	129	278	14.0	0.10
BKG_43	10/30/89	4.45	0.10	0.30	1.70	17.3	0.018	189.3	0.00	0.08	103	298	7.9	0.18
BKG_43	04/30/90	4.97	0.09	0.32	4.20	16.5	0.025	180.1	0.03	0.06	99	291	10.3	0.37
BKG_43	06/18/90	2.59	0.07	0.23	2.50	18.2	0.021	212.0	0.01	0.04	118	319	9.4	0.10
BKG_43	03/11/91	2.26	0.00	0.42	0.30	15.9	0.030	180.1	0.00	0.00	103	296	7.8	0.13
M1_2	02/08/88	ND	0.35	480	12	220	33	19	ND	0.03	880	ND	ND	41
M1_2	03/14/88	ND	0.40	320	10	340	61	14	0.38	ND	1400	ND	33	ND
M1_2	04/04/88	ND	0.54	350	13	260	34	20	0.18	0.12	1100	ND	20	53
M1_2	04/18/88	ND	0.14	290	15	221	30	23	0.10	0.08	727	ND	18	31
M1_2	05/09/88	ND	0.12	343	12	207	31	19	0.09	0.07	724	ND	15	27
M1_2	05/30/88	ND	0.27	674	12	391	44	21	0.14	0.02	1132	ND	24	49
M1_2	06/20/88	ND	0.30	536	19	307	47	28	0.09	0.15	956	ND	20	32
M1_2	07/25/88	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_2	08/22/88	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_2	09/19/88	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_2	10/17/88	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_2	11/14/88	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_2	01/09/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_2	03/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_2	04/10/89		0.00	0.51 ?	14	266	1 ?	62	0.07	0.05	793	2271	13	27
M1_2	05/22/89		0.13	114	16	275	32	26	0.25	0.05	756	2496	24	50
M1_2	06/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_2	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_2	08/21/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Well ID	Date Sampled	Cl (mg/l)	Cu (mg/l)	Fe (mg/l)	K (mg/l)	Mg (mg/l)	Mn (mg/l)	Na (mg/l)	Ni (mg/l)	Pb (mg/l)	S (mg/l)	SO4 (mg/l)	Si (mg/l)	Zn (mg/l)
M1_2	03/12/90		0.33	4 ?	15	344	39	32	0.45	0.22	989	2995	26	98
M1_2	04/30/90		0.12	1 ?	11	222	14	24	0.20	0.00	637	1872	26	44
M1_2	06/18/90		0.20	16	16	283	0	28	0.37	0.04	1028	2997	33	79
M1_3	02/08/88	ND	0.00	53.0	3.9	100	14.0 ?	180	ND	0.00	490	ND	ND	2.80
M1_3	03/14/88	ND	0.36	6.9	2.4	140	6.0	100	0.00	0.10	640	ND	11.0	1.10
M1_3	04/04/88	ND	0.06	19.0	2.8	73	3.6	110	0.01	0.04	230	ND	8.4	0.12
M1_3	04/18/88	ND	0.10	23.0	2.2	61	2.6	86	0.01	0.00	200	ND	7.6	0.78
M1_3	05/09/88	ND	0.00	7.1	2.2	39	1.8	68	0.00	0.03	133	ND	6.3	0.00
M1_3	05/30/88	ND	0.00	7.4	2.5	50	2.2	59	0.01	0.00	161	ND	8.5	0.00
M1_3	06/20/88	ND	0.00	11.0	3.8	57	3.5	147 ?	0.00	0.00	207	ND	9.0	0.75
M1_3	07/25/88	ND	0.00	4.7	3.0	40	1.4	37	0.01	0.00	128	381	6.3	0.00
M1_3	08/22/88	ND	0.02	4.3	2.3	37	1.4	30	0.00	0.03	344	351	6.8	0.02
M1_3	09/19/88	ND	0.20	3.7	2.9	33	1.4	35	0.00	0.07	127	408	6.2	0.13
M1_3	10/17/88	ND	0.00	5.5	4.2	45	1.7	51	0.00	0.04	160	373	8.0	0.22
M1_3	11/14/88	ND	0.03	11.3	5.2	63	2.3	104	0.01	0.08	252	654	8.2	1.88
M1_3	01/09/89	ND	0.03	13.6	6.2	131 ?	11.9	99	0.01	0.06	505	ND	13.3	0.48
M1_3	03/06/89	ND	0.07	18.1	5.2	187	21.7	63	0.01	0.17	667	1664	15.0	0.45
M1_3	04/10/89	ND	0.00	13.7	3.2	89	5.0	38	0.00	0.04	327	753	8.3	0.07
M1_3	05/22/89	ND	0.08	4.6	2.2	44	1.9	38	0.00	0.02	155	412	8.2	0.08
M1_3	06/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_3	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_3	08/21/89	ND	0.21	2.6	3.7	75	4.0	37	0.02	0.06	147	345	12.8	0.16
M1_3	10/30/89	3.46	0.12	7.1	2.8	36	1.5	37	0.00	0.14	125	380	6.8	0.19
M1_3	03/12/90	ND	0.25	56.4	4.7	169 ?	17.5	45	0.00	0.13	555	2060	11.3	0.77
M1_3	04/30/90	ND	0.06	16.5	3.7	98	5.4	66	0.00	0.00	301	ND	12.6	0.22
M1_3	06/18/90	ND	0.08	13.2	4.1	80	4.8	81	0.00	0.03	300	772	11.3	0.18
M1_3	03/11/91	ND	0.00	40.7	7.0	221 ?	22.4	87	0.05	0.18	634	2069	12.4	4.79
M1_3	06/03/91	ND	0.10	19.8	3.5	122	7.8	56	0.03	0.06	382	1065	10.3	0.18
M1_8	02/08/88	ND	0.00	120.0 ?	4.3	120	10.0 ?	28	ND	0.00	460	ND	ND	1.20
M1_8	03/14/88	ND	0.00	22.0	3.2	105	5.1	25	0.00	0.00	280	1460 ?	9.8	0.12
M1_8	04/04/88	ND	0.08	18.0	3.9	96	4.4	36	0.01	0.07	290	ND	11.0	0.06
M1_8	04/18/88	ND	0.13	26.0	4.0	89	4.2	30	0.01	0.01	330	ND	11.0	0.79
M1_8	05/09/88	ND	0.00	17.1	4.1	70	4.0	35	0.01	0.07	240	ND	11.9	0.00
M1_8	05/30/88	ND	0.00	6.4	2.8	41	2.1	29	0.00	0.00	174	ND	10.4	0.02
M1_8	06/20/88	ND	0.00	7.6	3.3	47	2.3	35	0.01	0.00	169	ND	11.1	0.05
M1_8	07/25/88	ND	0.00	3.2	2.6	35	1.5	25	0.01	0.00	160	473	9.8	0.00
M1_8	08/22/88	ND	0.01	3.5	2.0	29	1.5	24	0.00	0.05	395	401	10.4	0.01
M1_8	09/19/88	ND	0.10	2.5	2.2	24	1.2	24	0.00	0.08	117	383	8.3	0.04
M1_8	10/17/88	ND	0.00	4.4	3.1	28	1.2	36	0.01	0.03	123	318	10.6	0.14
M1_8	11/14/88	ND	0.01	3.9	3.5	30	1.3	37	0.02	0.03	135	340	11.2	0.16
M1_8	01/09/89	ND	0.00	5.1	3.4	48	2.1	35	0.00	0.09	194	616	10.3	0.02
M1_8	03/06/89	ND	0.06	18.1	3.5	106	4.4	36	0.02	0.14	351	1022	11.8	0.11
M1_8	04/10/89	ND	0.00	20.6	3.4	104	4.1	31	0.00	0.06	350	982	10.6	0.04
M1_8	05/22/89	ND	0.03	8.4	3.1	47	2.3	32	0.01	0.04	167	886	9.2	0.05
M1_8	06/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Well ID	Date Sampled	Cl (mg/l)	Cu (mg/l)	Fe (mg/l)	K (mg/l)	Mg (mg/l)	Mn (mg/l)	Na (mg/l)	Ni (mg/l)	Pb (mg/l)	S (mg/l)	SO4 (mg/l)	Si (mg/l)	Zn (mg/l)
M1_8	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M1_8	08/21/89	ND	0.23	17.7	2.2	109	7.3	18	0.00	0.07	222	549	13.1	0.23
M1_8	10/30/89	4.66	0.08	6.3	1.9	36	1.5	27	0.00	0.09	148	519	8.4	0.29
M1_8	03/12/90	ND	0.19	23.5	3.5	94	4.5	35	0.01	0.29 ?	348	998	10.7	0.19
M1_8	04/30/90	ND	0.07	20.3	3.5	106	4.0	34	0.00	0.30	359	ND	12.9	0.27
M1_8	06/18/90	ND	0.07	23.5	3.6	108	5.2	38	0.00	0.07	391	1127	11.7	0.11
M1_8	03/11/91	ND	0.00	40.3	3.9	169	7.5	42	0.01	0.01	475	1459	13.3	0.09
M2_4	02/08/88	ND	0.00	4.30 ?	3.5	56	13.0	15	ND	0.00	160	ND	ND	1.10
M2_4	03/14/88	ND	0 00	0.81	6.0	110	25.0	18	0.00	0.00	330	ND	17.0	0.02
M2_4	04/04/88	ND	0.07	1.70	6.4	92	21.0	23	0.01	0.09	290	ND	12.0	0.18
M2_4	04/18/88	ND	0.09	4.00	6.6	96	23.0	22	0.01	0.05	310	ND	15.0	0.97
M2_4	05/09/88	ND	0.01	1.33	7.2	101	19.7	24	0.01	0.00	288	ND	13.3	0.12
M2_4	05/30/88	ND	0.00	0.92	8.3	102	20.1	27	0.01	0.00	282	ND	16.1	0.01
M2_4	06/20/88	ND	0.00	1.87	6.6	92	16.6	19	0.00	0.00	237	ND	12.0	0.04
M2_4	07/25/88	ND	0.01	1.73	1.9	57	1.6 ?	42	0.00	0.04	234	695	11.0	0.00
M2_4	08/22/88	ND	0.02	0 24	5.1	87	19.7	17	0.00	0.03	760	897	14.2	0.02
M2_4	09/19/88	ND	0.09	0 20	6.2	72	17.0	19	0.00	0.07	216	749	12.3	0.05
M2_4	10/17/88	ND	0.00	1.34	9.4	89	18.2	31	0.02	0.08	292	713	16.4	0.11
M2_4	11/14/88	ND	0.01 ?	1.22 ?	5.4 ?	13 ?	1.2 ?	1814 ?	0.01 ?	0.04 ?	15 ?	36 ?	7.5 ?	0.28
M2_4	01/09/89	ND	0.01	0.86	6.5	86	15.6	46	0.02	0.02	279	953	13.5	0.12
M2_4	03/06/89	ND	0.07	1.01	6.3	118	28.5	22	0.01	0.18	332	902	16.6	0.16
M2_4	04/10/89	ND	0.00	0 59	6.7	100	21.1	28	0.00	0.00	320	891	12.9	0.07
M2_4	05/22/89	ND	0.10	1.08	6.1	119	26.5	24	0.00	0.05	342	771	19.2	0.32
M2_4	06/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M2_4	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M2_4	08/21/89	ND	0.18	1.25	9.7	152	44.6	27	0.00	0.09	303	850	16.6	0.18
M2_4	10/30/89	1.06	0.11	0.34	6.8	99	25.2	24	0.00	0.18	318	937	11.1	0.15
M2_4	03/12/90	ND	0.29	0.50	6.0	85	23.0	23	0.00	0.11	298	994	11.7	0.35
M2_4	04/30/90	ND	0.08	0.16	6.6	99	24.6	22	0.02	0.16	325	961	15.6	0.06
M2_4	06/18/90	ND	0.08	0.08	7.3	105	29.3	26	0.01	0.01	372	988	14.5	0.11
M2_6	02/08/88	ND	0.00	20.00 ?	4.5	62	17.0	17	ND	0.00	230	ND	ND	1.60
M2_6	03/14/88	ND	0.00	6.80	5.6	120	34.0	17	0.00	0.00	340	ND	16.0	0.04
M2_6	04/04/88	ND	0.11	13.60	7.2	140	32.0	21	0.01	0.05	470	ND	18.0	0.09
M2_6	04/18/88	ND	0.10	9.70	6.2	98	23.0	18	0.01	0.05	330	ND	14.0	0.59
M2_6	05/09/88	ND	0.02	2.60	7.1	101	21.3	25	0.00	0.00	274	ND	15.2	0.06
M2_6	05/30/88	ND	0.01	1.46 ?	5.2	99	18.0	24	0.00	0.00	248	ND	12.8	0.04
M2_6	06/20/88	ND	0.00	2.43	6.2	82	17.9	17	0.01	0.00	236	ND	13.3	0.04
M2_6	07/25/88	ND	0.00	2.15	7.0	86	18.3	21	0.01	0.00	290	863	14.4	0.00
M2_6	08/22/88	ND	0.03	4.11	5.1	92	23.3	17	0.00	0.02	829	895	13.1	0.02
M2_6	09/19/88	ND	0.12	3.35	6.3	71	16.4	20	0.00	0.11	243	792	12.2	0.05
M2_6	10/17/88	ND	0.00	5.72	8.2	96	25.4	26	0.00	0.07	372	753	16.7	0.22
M2_6	11/14/88	ND	0.01 ?	1.22 ?	6.1 ?	17 ?	2.6 ?	1217 ?	0.01 ?	0.09 ?	19 ?	51 ?	6.0 ?	0.39
M2_6	01/09/89	ND	0.23	5.22	7.3	107	19.3	47	0.01	0.00	310	974	16.1	0.37
M2_6	03/06/89	ND	0.06	2.05	6.0	100	20.6	27	0.00	0.14	291	896	14.9	0.15
M2_6	04/10/89	ND	0.00	1.04	5.7	82	13.8	49	0.00	0.00	313	796	12.7	0.13

Well ID	Date Sampled	Cl (mg/l)	Cu (mg/l)	Fe (mg/l)	K (mg/l)	Mg (mg/l)	Mn (mg/l)	Na (mg/l)	Ni (mg/l)	Pb (mg/l)	S (mg/l)	SO4 (mg/l)	Si (mg/l)	Zn (mg/l)
M2_6	05/22/89	ND	0.06	4.48	6.0	76	17.8	23	0.02	0.08	227	894	12.0	0.24
M2_6	06/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M2_6	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M2_6	08/21/89	ND	0.20	1.90	5.7	226 ?	53.5	17	0.01	0.07	354	858	18.3	0.27
M2_6	10/30/89	8.07	0.11	0.50	0.8	42	1.4 ?	46	0.00	0.09	159	472	8.4	0.14
M2_6	03/12/90	ND	0.21	1.35	4.9	78	20.2	20	0.00	0.08	258	1014	10.2	0.27
M2_6	04/30/90	ND	0.06	0.34	6.4	96	24.1	24	0.02	0.08	308	904	15.2	0.15
M2_6	06/18/90	ND	0.08	0.47	6.4	98	28.2	24	0.02	0.05	316	929	13.0	0.09
M2_12	02/08/88	ND	0.00	0.60	1.4	40	2.5	32	ND	0.00	150	ND	ND	0.00
M2_12	03/14/88	ND	0.14	2.30	1.5	110	5.6	31	0.00	0.05	450	890	18.0	0.03
M2_12	04/04/88	ND	0.15	2.30	2.3	100	4.3	49	0.00	0.11	480	ND	17.0	0.05
M2_12	04/18/88	ND	0.01	2.40	2.3	73	3.0	46	0.00	0.03	300	ND	10.0	0.00
M2_12	05/09/88	ND	0.00	1.41	2.0	75	2.8	50	0.00	0.00	273	ND	11.3	0.22
M2_12	05/30/88	ND	0.00	1.48	2.1	75	2.8	49	0.01	0.01	292	ND	13.8	0.00
M2_12	06/20/88	ND	0.00	2.24	2.1	58	1.8	41	0.00	0.00	208	ND	11.4	0.00
M2_12	07/25/88	ND	0.06	1.13	6.1 ?	127	25.5 ?	16	0.02	0.08	394	737	17.6	0.07
M2_12	08/22/88	ND	0.03	1.22	1.1	49	1.4	33	0.00	0.05	645	638	11.8	0.00
M2_12	09/19/88	ND	0.09	1.14	1.5	42	1.1	39	0.00	0.08	184	638	10.0	0.03
M2_12	10/17/88	ND	0.00	3.29	2.2	58	1.4	58	0.00	0.01	249	581	13.1	0.20
M2_12	11/14/88	ND	0.01 ?	1.32 ?	3.7 ?	38 ?	0.8 ?	753 ?	0.00 ?	0.11 ?	94 ?	268 ?	9.1 ?	0.23
M2_12	01/09/89	ND	0.03	1.06	2.2	48	1.4	92	0.01	0.02	172	499	12.8	0.07
M2_12	03/06/89	ND	0.06	2.90	1.8	43	2.1	65	0.02	0.17	170	458	12.4	0.09
M2_12	04/10/89	ND	0.00	1.13	2.1	75	2.2	58	0.00	0.10	285	803	11.2	0.05
M2_12	05/22/89	ND	0.07	1.00	1.9	62	1.3	46	0.00	0.09	270	399	9.5	0.08
M2_12	06/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	394	ND	ND
M2_12	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M2_12	08/21/89	ND	0.17	1.14	0.8	51	1.6	25	0.00	0.08	121	ND	9.7	0.15
M2_12	10/30/89	7.69	0.13	0.66 ?	6.8	101	26.6 ?	23	0.01	3.57 ?	316	955	10.9	0.53
M2_12	03/12/90	7.36	0.21	0.76 ?	1.1	45	3.1	42	0.01	0.13	160	544	8.8	0.29
M2_12	04/30/90	7.62	0.06	0.29	0.8	38	1.0	48	0.01	0.02	153	452	11.5	0.06
M2_12	06/18/90	ND	0.07	0.35	1.7	43	1.4	47	0.01	0.03	168	473	10.4	0.07
M3_10	02/08/88	ND	0.00	5.50	2.4	38	2.0	24	ND	0.00	120	ND	ND	0.00
M3_10	03/14/88	ND	0.00	1.50	2.1	36	1.8	24	0.00	0.00	120	790 ?	11.0	0.02
M3_10	04/04/88	ND	0.12	4.10	2.6	52	2.8	22	0.00	0.14 ?	190	ND	14.0	0.03
M3_10	04/18/88	ND	0.10	4.50	1.6	35	2.0	21	0.01	0.00	140	ND	10.0	0.46
M3_10	05/09/88	ND	0.00	3.37	2.0	31	1.8	22	0.00	0.02	118	ND	9.0	0.00
M3_10	05/30/88	ND	0.00	4.69	1.9	39	2.3	20	0.00	0.00	151	ND	11.3	0.03
M3_10	06/20/88	ND	0.00	8.48	2.8	31	2.2	28	0.00	0.00	150	ND	12.2	0.04
M3_10	07/25/88	ND	0.00	3.30	2.0	35	1.8	22	0.00	0.05	136	404	9.0	0.01
M3_10	08/22/88	ND	0.00	3.77	1.6	40	2.0	16	0.00	0.06	422 ?	766 ?	9.8	0.00
M3_10	09/19/88	ND	0.07	3.20	1.9	32	1.7	21	0.00	0.06	139	428	9.5	0.03
M3_10	10/17/88	ND	0.00	4.28	2.5	38	1.8	29	0.00	0.00	153	382	11.6	0.14
M3_10	11/14/88	ND	0.01	6.08	2.6	37	2.0	29	0.00	0.03	139	387	11.6	0.19
M3_10	01/09/89	ND	0.02	15.33 ?	2.6	40	2.1	25	0.01	0.00	148	395	11.0	2.04
M3_10	03/06/89	ND	0.05	2.93	2.4	37	2.1	25	0.00	0.26	140	347	11.0	0.11

Well ID	Date Sampled	Cl (mg/l)	Cu (mg/l)	Fe (mg/l)	K (mg/l)	Mg (mg/l)	Mn (mg/l)	Na (mg/l)	Ni (mg/l)	Pb (mg/l)	S (mg/l)	SO4 (mg/l)	Si (mg/l)	Zn (mg/l)
M3_10	04/10/89	ND	0.00	1.57	2.3	35	1.6	22	0.00	0.05	145	378	10.0	0.07
M3_10	05/22/89	ND	0.06	2.19	1.7	34	1.7	21	0.00	0.04	132	292	9.7	0.06
M3_10	06/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M3_10	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M3_10	08/21/89	ND	0.14	2.95	2.9	60	4.0	25	0.00	0.00	173	409	15.2	0.19
M3_10	10/30/89	6.78	0.12	2.84	1.5	33	1.8	22	0.00	0.80	133	382	7.5	0.18
M3_10	03/12/90	ND	0.22	0.37 ?	1.8	33	1.8	18	0.00	0.15	135	427	8.2	0.17
M3_10	04/30/90	ND	0.08	2.21	2.0	36	2.3	23	0.02	0.05	152	440	11.5	0.11
M3_10	06/18/90	ND	0.06	1.63	2.7	41	2.6	25	0.00	0.07	177	484	10.8	0.08
M3_10	03/11/91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M4_5	02/08/88	ND	0.00	0.03	12.0	200	0.60	30	ND	0.00	560	ND	ND	0.22
M4_5	03/14/88	ND	0.24	0.39	5.5	210	3.20	14	0.00	0.19 ?	900	ND	20.0	0.45
M4_5	04/04/88	ND	0.11	0.22	9.7	230	1.30	24	0.00	0.08	910	ND	23.0	0.32
M4_5	04/18/88	ND	0.18	1.10	8.8	182	1.30	25	0.00	0.00	630	ND	15.0	0.18
M4_5	05/09/88	ND	0.05	0.04	9.5	168	1.03	25	0.00	0.05	565	ND	13.7	0.23
M4_5	05/30/88	ND	0.01	0.15	9.3	227	1.40	24	0.01	0.00	670	ND	20.2	0.31
M4_5	06/20/88	ND	0.00	0.59	12.1	223	2.86	46	0.00	0.00	632	ND	19.1	0.26
M4_5	07/25/88	ND	0.00	0.48	9.3	216	1.15	26	0.00	0.00	888	2649	18.3	1.01
M4_5	08/22/88	ND	0.11	0.11	6.3	250	3.57	24	0.06	0.09	2723 ?	2361	18.6	0.41
M4_5	09/19/88	ND	0.09	0.11	5.6	176	5.59	49	0.00	0.01	678	1235	15.1	0.30
M4_5	11/14/88	ND	0.09	1.66	7.0	242	10.35 ?	46	0.01	0.05	1080	1840	25.5	0.50
M4_5	01/09/89	ND	0.07	1.71	11.9	306	1.65	33	0.01	0.09	1076	2274	23.9	0.85
M4_5	03/06/89	ND	0.08	1.57	10.4	229	2.19	44	0.02	0.14	754	1800	19.2	0.30
M4_5	04/10/89	ND	0.00	0.64	7.2	169	1.54	28	0.00	0.14	524	1086	14.0	0.20
M4_5	05/22/89	ND	0.26	1.30	6.5	225	1.15	21	0.00	0.12	612	6024 ?	18.3	0.29
M4_5	06/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M4_5	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M4_5	08/21/89	ND	0.23	1.02	6.6	385	0.88	14	0.00	0.07	675	1867	25.4	0.52
M4_5	10/30/89	14.83	0.15	0.08	6.8	193	3.28	35	0.01	5.21 ?	624	1832	12.8	0.40
M4_5	03/12/90	ND	0.25	0.51	7.6	174	0.33	35	0.00	0.22	566	1980	13.7	0.47
M4_5	04/30/90	ND	0.09	0.00	9.9	214	0.13	29	0.00	0.00	690	1893	18.7	0.25
M4_5	06/18/90	ND	0.08	0.02	10.6	206	0.22	32	0.00	0.05	741	2100	17.6	0.39
M4_5	03/11/91	ND	0.21	0.28	11.3	250	0.50	40	0.00	0.39	904	1960	16.8	0.52
M4_5	06/03/91	ND	0.09	0.54	8.9	228	0.25	27	0.04	0.01	721	2016	14.6	0.30
M4_7	02/08/88	ND	0.00	5.40	2.00	150	0.92	54	ND	0.00	490	ND	ND	0.06
M4_7	03/14/88	ND	0.20	4.30	0.92	150	1.10	29	0.00	0.04	800	ND	16.0	0.08
M4_7	04/04/88	ND	0.37	3.10	1.80	200	1.10	28	0.04	0.11	1000	ND	19.0	0.09
M4_7	04/18/88	ND	0.17	0.00	1.40	140	0.98	36	0.02	0.30	800	ND	13.0	0.29
M4_7	05/09/88	ND	0.00	0.11	8.08	169	1.14	23	0.00	0.02	527	ND	12.5	0.08
M4_7	05/30/88	ND	0.05	1.87	1.53	235	1.53	42	0.01	0.01	1027	ND	18.2	0.05
M4_7	06/20/88	ND	0.10	1.08	3.40	178	1.02	209 ?	0.03	0.00	689	ND	20.1	0.07
M4_7	07/25/88	ND	2.85 ?	0.23	1.94	171	0.69	59	0.03	0.00	725	2159	15.5	0.00
M4_7	08/22/88	ND	0.09	0.37	1.18	180	0.80	37	0.00	0.00	2042 ?	2159	15.1	0.03
M4_7	09/19/88	ND	0.14	0.31	1.90	143	0.78	40	0.02	0.12	566	1892	11.8	0.08
M4_7	10/17/88	ND	0.03	2.74	2.30	213	0.86	54	0.03	0.00	776	1692	15.6	0.20

Well ID	Date Sampled	Cl (mg/l)	Cu (mg/l)	Fe (mg/l)	K (mg/l)	Mg (mg/l)	Mn (mg/l)	Na (mg/l)	Ni (mg/l)	Pb (mg/l)	S (mg/l)	SO4 (mg/l)	Si (mg/l)	Zn (mg/l)
M4_7	11/14/88	ND	0.04	2.78	2.80	182	1.33	62	0.00	0.14	741	1876	21.4	0.19
M4_7	01/09/89	ND	0.03	1.16	2.20	158	0.88	57	0.00	0.00	551	2070	14.9	0.14
M4_7	03/06/89	ND	0.12	3.04	1.70	171	1.60	35	0.01	0.14	645	1669	16.8	0.24
M4_7	04/10/89	ND	0.00	1.46	2.20	175	0.89	50	0.00	0.00	722	1742	14.2	0.08
M4_7	05/22/89	ND	0.06	1.12	1.30	173	1.91	53	0.00	0.04	588	509 ?	14.7	0.06
M4_7	06/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M4_7	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M4_7	08/21/89	ND	0.18	1.15	3.10	254	1.75	93	0.00	0.04	700	1737	19.5	0.14
M4_7	10/30/89	16.26	0.12	0.97	1.70	170	0.56	88	0.00	0.10	618	1722	11.8	0.20
M4_7	03/12/90	ND	0.61	1.14	2.00	155	0.88	100	0.00	0.25	625	1814	13.6	0.60
M4_7	04/30/90	ND	0.14	0.00	2.80	176	0.54	126	0.00	0.11	653	1837	17.1	0.09
M4_7	06/18/90	ND	0.07	0.46	2.30	146	0.69	109	0.00	0.04	653	1921	13.4	0.12
M4_7	03/11/91	ND	0.18	1.25	0.50	172	0.70	87	0.02	0.34	624	1856	12.2	0.30
M4_10	02/08/88	ND	0.00	2.00	7.40	32	0.24	1400	ND	0.00	600	ND	ND	0.00
M4_10	03/14/88	ND	0.03	4.40	3.20	69	0.74	470	0.00	0.00	520	ND	21.0	0.03
M4_10	04/04/88	ND	0.23	0.33	6.95	89	0.68	544	0.00	0.08	557	ND	15.1	0.03
M4_10	04/18/88	ND	0.28	0.00	6.60	93	0.76	440	0.00	0.03	630	ND	17.0	0.51
M4_10	05/09/88	ND	0.02	2.21	5.66	89	0.73	416	0.00	0.06	515	ND	15.3	0.00
M4_10	05/30/88	ND	0.05	1.04	7.06	146	1.13	305	0.00	0.00	752	ND	19.4	0.06
M4_10	06/20/88	ND	0.10	2.07	10.09	144	1.25	244	0.02	0.00	669	ND	26.0	0.05
M4_10	07/25/88	ND	0.12	0.67	5.69	170	0.85	115	0.03	0.00	823	2451	23.2	0.00
M4_10	08/22/88	ND	0.13	1.40	5.25	203	1.27	100	0.00	0.09	2026 ?	2306	20.5	0.26
M4_10	09/19/88	ND	0.17	1.02	4.90	121	0.95	104	0.00	0.10	589	1868	16.0	0.07
M4_10	10/17/88	ND	0.02	4.56	7.20	179	1.15	145	0.00	0.03	723	1973	25.3	0.13
M4_10	11/14/88	ND	0.12	6.66	7.00	218	1.42	113	0.06	0.13	680	1834	29.0	0.94
M4_10	01/09/89	ND	0.08	2.48	5.30	262	1.43	83	0.01	0.01	673	2014	26.0	0.11
M4_10	03/06/89	ND	0.06	4.29	4.50	250	1.29	76	0.01	0.19	624	1653	23.1	0.11
M4_10	04/10/89	ND	0.03	3.26	3.80	189	1.53	98	0.00	0.08	717	1673	24.9	0.07
M4_10	05/22/89	ND	0.11	5.46	3.30	122	1.55	70	0.00	0.07	640	1369	22.7	0.12
M4_10	06/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M4_10	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M4_10	08/21/89	ND	0.09	6.78	4.20	153	1.28	77	0.00	0.05	755	1682	29.9	0.16
M4_10	10/30/89	20.81	0.13	1.62	2.50	137	1.33	62	0.00	2.64 ?	584	1702	13.7	0.31
M4_10	03/12/90	ND	0.22	3.30	2.50	143	1.30	63	0.00	0.17	592	1686	17.5	0.18
M4_10	04/30/90	ND	0.10	0.00	2.60	124	1.18	53	0.01	0.00	597	1682	19.9	0.08
M4_10	06/18/90	ND	0.08	2.60	2.60	135	1.37	50	0.00	0.05	647	1820	16.1	0.12
M4_10	03/11/91	ND	0.00	2.04	1.70	140	1.30	52	0.01	0.00	550	1719	14.6	0.04
M5_4	02/08/88	ND	0.00	0.80	5.40	100	1.10	79	ND	0.00	360	ND	ND	0.03
M5_4	03/14/88	ND	0.02	0.37	3.90	130	1.40	76	0.00	0.04	440	ND	15.0	0.00
M5_4	04/04/88	ND	0.17	0.39	4.80	160	1.10	82	0.01	0.11	640	ND	18.0	0.04
M5_4	04/18/88	ND	0.18	0.89	4.00	130	0.49	46	0.04	0.04	420	ND	13.0	0.75
M5_4	05/09/88	ND	0.02	0.17	3.58	106	0.57	86	0.00	0.07	377	ND	10.2	0.00
M5_4	05/30/88	ND	0.05	0.09	4.52	173	0.31	50	0.01	0.00	508	ND	16.3	0.02
M5_4	06/20/88	ND	0.00	0.67	5.38	124	0.24	53	0.00	0.00	406	ND	16.8	0.01
M5_4	07/25/88	ND	0.21	4.95 ?	4.47	115	0.20	47	0.02	0.00	428	1276	15.9	0.57

Well ID	Date Sampled	Cl (mg/l)	Cu (mg/l)	Fe (mg/l)	K (mg/l)	Mg (mg/l)	Mn (mg/l)	Na (mg/l)	Ni (mg/l)	Pb (mg/l)	S (mg/l)	SO4 (mg/l)	Si (mg/l)	Zn (mg/l)
M5_4	08/22/88	ND	0.02	0.03	3.18	115	0.16	44	0.00	0.00	1212 ?	1134	15.5	0.01
M5_4	09/19/88	ND	0.10	0.03	4.06	91	0.04	35	0.00	0.09	296	962	12.8	0.06
M5_4	10/17/88	ND	0.01	1.33	7.20	113	0.12	40	0.00	0.01	341	835	17.9	0.18
M5_4	11/14/88	ND	0.02	1.06	2.60	57	0.04	87	0.04	0.08	262	894	13.6	0.11
M5_4	01/09/89	ND	0.03	0.29	5.00	116	0.04	33	0.00	0.03	329	1045	16.6	0.02
M5_4	03/06/89	ND	0.07	0.71	4.40	120	0.32	49	0.02	0.12	383	932	18.3	0.11
M5_4	04/10/89	ND	0.00	1.38	4.90	125	0.24	51	0.00	0.02	459	1264	13.2	0.08
M5_4	05/22/89	ND	0.07	0.59	4.70	163	0.06	44	0.00	0.06	475	1882	14.0	0.06
M5_4	06/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M5_4	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M5_4	08/21/89	ND	0.25	1.60	4.00	213	0.16	25	0.00	0.01	331	942	21.6	0.20
M5_4	10/30/89	10.64	0.13	0.19	3.60	96	0.12	33	0.00	0.42	304	895	10.6	0.15
M5_4	03/12/90	ND	0.19	0.50	3.70	112	0.34	34	0.00	0.20	395	1173	10.9	0.90
M5_4	04/30/90	ND	0.07	0.32	2.70	112	0.21	49	0.01	0.06	370	1027	14.1	0.05
M5_4	06/18/90	ND	0.06	0.67	3.10	99	0.41	84	0.00	0.02	385	1048	11.6	0.13
M5_4	03/11/91	ND	0.00	0.29	3.50	105	0.08	53	0.05	0.11	376	1184	11.5	0.09
M5_4	06/03/91	29.77	0.06	0.50	1.30	99	0.26	99	0.02	0.00	352	969	10.3	0.05
M5_23	02/08/88	ND	0.00	0.05	2.10	8	0.06	140	ND	0.01	66	ND	ND	0.04
M5_23	03/14/88	ND	0.00	0.00	0.96	9	0.08	140	0.00	0.02	93	ND	12.0	0.03
M5_23	04/04/88	ND	0.02	0.09	0.74	11	0.09	140	0.00	0.05	100	ND	14.0	0.02
M5_23	04/18/88	ND	0.12	6.50 ?	0.53	10	0.19	93	0.00	0.02	84	ND	11.0	0.95
M5_23	05/09/88	ND	0.00	0.00	0.19	6	0.07	71	0.01	0.04	58	ND	8.4	0.08
M5_23	05/30/88	ND	0.00	0.05	0.37	11	0.13	103	0.00	0.00	100	ND	16.2	0.01
M5_23	06/20/88	ND	0.00	1.56	1.13	10	0.14	117	0.00	0.00	80	ND	14.5	0.08
M5_23	07/25/88	ND	0.00	0.72	0.54	9	0.13	87	0.00	0.06	83	246	14.1	0.05
M5_23	08/22/88	ND	0.07	0.00	0.14	7	0.00	69	0.00	0.04	202	294	11.0	0.00
M5_23	09/19/88	ND	0.15	0.38	0.33	8	0.07	105	0.00	0.06	94	239	12.0	0.10
M5_23	10/17/88	ND	0.00	0.84	0.40	7	0.06	116	0.01	0.01	80	219	12.4	0.00
M5_23	11/14/88	ND	0.04	1.64	2.90	53 ?	0.09	103	0.05	0.02	206	230	16.5	0.16
M5_23	01/09/89	ND	0.02	0.33	0.80	7	0.08	122	0.00	0.02	86	243	12.5	0.20
M5_23	03/06/89	ND	0.09	58.54 ?	1.20	46 ?	0.58 ?	108	0.00	0.07	162	201	16.3	10.03
M5_23	04/10/89	ND	0.00	0.78	0.50	7	0.07	113	0.00	0.11	93	234	11.6	0.16
M5_23	05/22/89	ND	0.08	10.24	0.00	13	0.22	74	0.00	0.03	86	72 ?	13.8	0.08
M5_23	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M5_23	08/21/89	ND	0.17	0.72	0.30	14	0.28	46	0.00	0.06	59	192	15.4	0.10
M5_23	10/30/89	1.97	0.09	0.06	0.00	7	0.08	84	0.00	0.17	67	205	8.7	0.14
M5_23	03/12/90	ND	0.19	2.35	0.20	7	0.15	84	0.00	0.25	71	190	11.4	0.24
M5_23	04/30/90	ND	0.08	0.12	0.60	7	0.08	91	0.02	0.06	69	ND	13.7	0.08
M5_23	06/18/90	1.43	0.07	0.07	0.70	7	0.09	97	0.00	0.02	78	208	12.6	0.07
M5_23	03/11/91	2.08	0.16	0.28	0.30	7	0.20	72	0.02	0.33	55	186	8.6	0.41
M5_53	12/09/87	ND	0.04	1.70	0.25	1.7	0.04	107	ND	ND	63	ND	ND	0.40
M5_53	02/08/88	ND	0.00	0.00	0.29	0.6	0.02	140	ND	0.00	53	ND	ND	0.00
M5_53	03/14/88	ND	0.00	0.10	0.06	0.3	0.02	110	0.00	0.02	49	230	6.0	0.00
M5_53	04/04/88	ND	0.00	0.04	0.09	0.6	0.02	140	0.00	0.04	56	ND	7.3	0.00
M5_53	04/18/88	ND	0.08	0.92	0.22	0.7	0.06	120	0.00	0.03	62	ND	6.4	0.37

Well ID	Date Sampled	Cl (mg/l)	Cu (mg/l)	Fe (mg/l)	K (mg/l)	Mg (mg/l)	Mn (mg/l)	Na (mg/l)	Ni (mg/l)	Pb (mg/l)	S (mg/l)	SO4 (mg/l)	Si (mg/l)	Zn (mg/l)
M5_53	05/09/88	ND	0.00	0.00	0.00	0.1	0.00	92	0.00	0.00	45	ND	4.6	0.00
M5_53	05/30/88	ND	0.00	0.07	0.06	0.6	0.06	118	0.00	0.00	69	ND	7.4	0.01
M5_53	06/20/88	ND	0.00	0.54	0.17	0.7	0.02	152	0.00	0.00	62	ND	7.9	0.00
M5_53	07/25/88	ND	0.00	0.58	0.28	0.1	0.01	116	0.00	0.00	53	158	6.0	0.00
M5_53	08/22/88	ND	0.00	0.00	0.00	0.8	0.00	117	0.00	0.01	166 ?	203	6.2	0.00
M5_53	09/19/88	ND	0.09	0.05	0.05	0.5	0.00	115	0.00	0.11 ?	60	155	5.6	0.04
M5_53	10/17/88	ND	0.00	0.72	0.10	0.1	0.00	122	0.00	0.00	58	163	5.6	0.00
M5_53	11/14/88	ND	0.00	0.84	0.30	0.6	0.01	136	0.00	0.04	56	161	6.4	0.04
M5_53	01/09/89	ND	0.00	0.54	0.40	0.2	0.00	131	0.00	0.02	60	160	6.3	0.05
M5_53	03/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M5_53	04/10/89	ND	0.00	0.49	0.20	0.3	0.00	114	0.00	0.05	57	159	5.8	0.05
M5_53	05/22/89	ND	0.19	2.07 ?	0.00	0.4	0.06	104	0.00	0.08	100	141	10.2	0.28
M5_53	06/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M5_53	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
M5_53	08/21/89	ND	0.16	1.15	0.20	1.3	0.08	64	0.00	0.00	45	163	6.6	0.11
M5_53	10/30/89	1.79	0.07	0.05	0.00	0.4	0.01	119	0.00	0.03	57	164	4.3	0.17
M5_53	03/12/90	2.15	0.19	0.36	0.00	0.6	0.05	100	0.01	0.17	46	162	4.8	0.21
M5_53	04/30/90	1.95	0.07	0.16	0.70	0.4	0.01	118	0.00	0.04	55	160	7.2	0.06
M5_53	06/18/90	1.17	ND	ND	ND	ND	ND	ND	ND	ND	ND	172	ND	ND
M5_53	03/11/91	ND	0.00	0.50	0.00	0.4	0.02	135	0.00	0.03	55	157	5.6	0.07
		Wells in the vadose or saturated zones of the tailings												
B1-4	12/09/87	ND	0.075	96	12.0	76	1.8	26	ND	ND	290	ND	ND	14.00
B1-4	02/08/88	ND	0.22	120	8.0	77	2.6	17	ND	0.05	290	ND	ND	11.00
B1-4	03/14/88	ND	0.24	74	14.0	86	2.4	19	0.14	0.05	270	ND	50.0	6.70
B1-4	04/04/88	ND	37.0	97	16.0	200	3.7	11	0.16	0.17	720	ND	70.0	6.40
B1-4	04/18/88	ND	26.0	85	14.0	140	2.8	7	0.18	0.14	540	ND	66.0	6.30
B1-4	05/09/88	ND	17.0	64	14.0	110	2.2	7	0.09	0.05	420	ND	69.0	4.50
B1-4	06/20/88	ND	29.0	170	45.0 ?	210	3.9	9	0.35	0.28	790	ND	140.0	9.30
B1-4	07/25/88	ND	12.0	82	8.7	98	2.1	9	0.19	0.65	450	ND	69.0	8.80
B1-4	08/22/88	ND	11.0	93	16.0	110	2.0	9	0.11	0.45	460	ND	84.0	8.00
B1-4	09/19/88	ND	8.9	86	9.8	100	2.2	3	0.11	0.09	310	ND	75.0	7.00
B1-4	11/14/88	ND	8.5	99	18.0	100	2.1	6	0.14	0.07	360	ND	73.0	7.10
B1-4	01/09/89	13 ?	6.1	70	19.0	74	1.7	4	1.30	0.26	300	320	44.0	13.00
B1-4	04/11/89	2	17.0	25	5.3	40	1.0	4	0.09	0.22	190	300	44.0	3.40
B1-4	06/06/89	2	7.2	23	2.2	19	0.4	2	0.08	0.35	86	88 ?	55.0	1.70
B1-4	08/21/89	2	7.4	54	5.8	30	0.9	5	1.40	0.31	130	420	77.0	6.00
B1-4	10/29/89	ND	5.5	78	5.3	29	0.9	3	0.18	0.06	160	ND	58.0	6.30
B1-4	03/12/90	ND	13.0	50	2.9	64	1.7	5	0.18	0.35	290	ND	52.0	5.30
B1-4	04/30/90	ND	13.0	47	2.2	60	1.4	3	0.05	0.05	290	ND	64.0	4.00
B1-7	12/09/87	ND	12	79	3.5	50	1.5	46	ND	ND	610	ND	ND	5.10
B1-7	02/08/88	ND	13	120	1.4	55	2.6	37	ND	0.15	550	ND	ND	6.80
B1-7	03/14/88	ND	14	130	4.4	83	3.3	48	0.05	0.07	640	ND	31.0	7.60
B1-7	04/04/88	ND	45	690	4.6	350	9.8	52	0.17	0.06	1600	ND	51.0	28.00

Well ID	Date Sampled	Cl (mg/l)	Cu (mg/l)	Fe (mg/l)	K (mg/l)	Mg (mg/l)	Mn (mg/l)	Na (mg/l)	Ni (mg/l)	Pb (mg/l)	S (mg/l)	SO4 (mg/l)	Si (mg/l)	Zn (mg/l)
B1-7	04/18/88	ND	64	720	3.6	380	10.0	46	0.21	0.05	1900	ND	44.0	38.00
B1-7	05/09/88	ND	120	860	6.5	400	9.8	60	0.23	0.24	2200	ND	52.0	41.00
B1-7	06/20/88	ND	200	1100	4.8	490	11.0	48	0.69	0.15	2800	ND	56.0	60.00
B1-7	07/25/88	ND	180	940	7.1	440	11.0	51	0.20	0.97	3400	20000 ?	54.0	70.00
B1-7	08/22/88	ND	140	920	4.6	380	9.3	28	0.28	0.09	3200	ND	49.0	49.00
B1-7	09/19/88	ND	130	900	2.8	390	10.0	28	0.21	0.50	2200	ND	53.0	52.00
B1-7	11/14/88	ND	120	900	9.1	390	9.3	25	0.49	0.05	2300	ND	76.0	53.00
B1-7	01/09/89	46	81	570	7.7	260	6.1	19	0.94	0.46	1700	6400	38.0	41.00
B1-7	03/06/89	ND	83	600	2.0	300	6.9	23	0.18	0.70	1900	ND	46.0	35.00
B1-7	04/11/89	38	70	510	3.8	250	5.6	20	0.32	0.17	1700	1400	33.0	32.00
B1-7	06/06/89	2	99	610	0.9	290	10.0	30	0.09	1.50	2000	7200	44.0	34.00
B1-7	08/21/89	120 ?	160	1100	3.1	420	14.0	39	0.61	0.05	2900	9600	60.0	67.00
B1-7	10/29/89	ND	140	940	2.5	470	10.0	30	0.40	0.48	3000	ND	46.0	51.00
B1-7	03/12/90	ND	140	920	1.8	410	9.0	35	0.17	0.32	2500	ND	43.0	56.00
B1-7	04/30/90	ND	44	700	0.9	330	9.0	40	0.14	0.17	1500	ND	36.0	33.00
B1-16	12/09/87	ND	6.6	950	58.0	200	30	27	ND	ND	7500	ND	ND	200.00
B1-16	02/08/88	ND	12.0	7300	53.0	1000	160	24	ND	3.60	5900	ND	ND	610.00
B1-16	03/14/88	ND	4.6	4600	40.0	910	94	20	2.00	2.90	6900	ND	22	770.00
B1-16	04/04/88	ND	9.6	7500	62.0	1100	170	28	3.60	4.80	9600	ND	33	1000.00
B1-16	04/18/88	ND	12.0	7900	69.0	1200	130	28	3.40	4.00	10000	ND	28	810.00
B1-16	05/09/88	ND	7.9	14000	83.0	2500	160	33	3.80	5.40	14000	ND	33	1800.00
B1-16	06/20/88	ND	8.8	12000	60.0	2300	140	16	3.20	4.50	13000	ND	30	1600.00
B1-16	07/25/88	ND	32.0	12000	0.1	2800	190	97	4.50	3.90	21000	120000 ?	49	2000.00
B1-16	08/22/88	ND	14.0	11000	50.0	2000	140	29	2.90	3.90	16000	ND	28	1333.00
B1-16	09/19/88	ND	560.0 ?	5700	38.0	2100	61	130	2.20	1.60	10000	ND	180 ?	900.00
B1-16	11/14/88	ND	13.0	20000	100.0	3900	220	28	4.70	5.60	22000	ND	65	2500.00
B1-16	01/09/89	2	9.3	13000	75.0	2500	160	21	3.50	5.50	16000	51000	40	1600.00
B1-16	03/06/89	ND	13.0	15000	55.0	2900	170	26	4.10	7.20	17000	ND	52	1600.00
B1-16	04/11/89	870	18.0	25000	100.0	5100	280	68	6.30	11.00	32000	7500	77	3000.00
B1-16	06/06/89	8800 ?	50.0	850	0.1	170	10	21	0.62	8.70	1400	49000	34	96.00
B1-16	08/21/89	340	16.0	12000	49.0	1900	130	66	2.50	6.30	10000	49000	36	1200.00
B1-16	10/29/89	ND	18.0	11000	43.0	1900	110	34	2.20	4.80	12000	ND	31	1000.00
B1-16	03/12/90	ND	23.0	10000	36.0	1800	110	33	2.30	5.70	12000	ND	38	1000.00
B1-16	04/30/90	ND	24.0	9700	46.0	2100	120	19	2.50	3.50	14000	ND	39	1100.00
B2-4	12/09/87	ND	160	950	4.5	200	8	23	ND	ND	3200	ND	ND	150
B2-4	02/08/88	ND	240	1800	1.5	300	10	17	ND	0.1	2800	ND	ND	130
B2-4	03/14/88	ND	210	1800	7.1	380	12	21	0.34	0.22	3100	ND	72	120
B2-4	04/04/88	ND	210	2300	2.6	460	10	16	0.42	0.37	3800	ND	110	180
B2-4	04/18/88	ND	170	2900	5.6	460	11	15	0.41	0.25	3800	ND	90	240
B2-4	05/09/88	ND	270	4000	1.3	620	14	19	0.57	0.88	5200	ND	110	370
B2-4	06/20/88	ND	210	2500	0.83	420	6	7	0.41	0.38	3700	ND	110	220
B2-4	07/25/88	ND	220	2900	0.1	510	13	55 ?	0.68	1.50	5700	ND	160	270
B2-4	08/22/88	ND	100	1500	0.1	250	6	15	0.20	0.63	2600	ND	87	120
B2-4	09/19/88	ND	12	9000 ?	46.0 ?	1600 ?	110 ?	9	2.24 ?	3.60 ?	8900 ?	ND	23	1100
B2-4	11/14/88	ND	130	2100	4.7	330	7	11	0.07	0.07	2700	ND	150	140

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B2-4	01/09/89	36	83	1400	5.9	210	5	12	0.66	0.44	1900	7400	77	94
B2-4	03/06/89	ND	78	1500	6.4	240	6	13	0.24	0.89	2100	ND	86	90
B2-4	04/11/89	2	96	1500	0.1	280	6	13	0.34	1.40	2400	1500 ?	76	75
B2-4	06/06/89	2	100	1300	0.4	230	6	12	0.05	0.74	2200	7900	110	47
B2-4	08/21/89	110 ?	82	1600	1.8	210	7	17	0.31	0.91	2000	7500	110	63
B2-4	10/29/89	ND	70	1500	2.2	220	6	14	0.25	0.32	2200	ND	78	60
B2-4	03/12/90	ND	100	1700	0.7	250	7	17	0.35	1.10	2500	ND	65	70
B2-4	04/30/90	ND	140	1500	2.6	250	6	10	0.18	0.11	2300	ND	80	63
B2-8	12/09/87	ND	28	240	4.8	100	4	25	ND	ND	940	ND	ND	43
B2-8	02/08/88	ND	50	280	2.0	120	7	21	ND	0.28	830	ND	ND	53
B2-8	03/14/88	ND	32	310	12.0	140	7	21	0.22	0.10	860	ND	26	47
B2-8	04/04/88	ND	34	340	4.2	140	6	20	0.25	0.09	930	ND	27	51
B2-8	04/18/88	ND	50	530	5.3	220	8	25	0.52	0.15	1100	ND	26	77
B2-8	05/09/88	ND	63	970	4.3	370	11	34	0.44	0.21	1800	ND	30	140
B2-8	06/20/88	ND	77	1100	5.7	410	11	25	0.42	0.21	2100	ND	31	160
B2-8	07/25/88	ND	86	900	4.6	380	11	38	0.09	1.50	2500	ND	29	160
B2-8	09/19/88	ND	53	680	5.8	140	7	18	0.07	2.70	1100	ND	29	67
B2-8	11/14/88	ND	150	1500	8.3	580	14	28	0.34	0.05	2900	ND	45	240
B2-8	01/09/89	25	130	1400	6.9	520	14	31	0.56	0.36	2900	11000	36	220
B2-8	03/06/89	ND	120	1400	17.0	560	14	30	0.63	0.95	2800	ND	38	210
B2-8	04/11/89	2	120	1400	1.5	550	14	32	0.84	1.10	3200	2500 ?	36	210
B2-8	08/21/89	140 ?	160	1600	4.4	540	15	34	0.78	0.57	3700	12000	50	270
B2-8	10/29/89	ND	120	1500	3.4	460	11	30	0.71	0.28	3300	ND	35	220
B2-8	03/12/90	ND	140	1700	2.6	470	13	30	0.37	1.40	3500	ND	29	240
B2-8	04/30/90	ND	130	1700	6.9	480	11	26	0.51	0.16	3600	ND	33	230
B2-16	12/09/87	ND	38	450	4.8	82	4	19	ND	ND	1100	ND	ND	40
B2-16	02/08/88	ND	59	740	3.2	110	7	17	ND	2.70	970	ND	ND	54
B2-16	03/14/88	ND	43	690	4.2	130	9	17	0.17	2.10	1200	ND	29	62
B2-16	04/04/88	ND	64	1100	5.1	210	11	18	0.30	3.60	1800	ND	36	110
B2-16	04/18/88	ND	62	890	4.9	180	10	17	0.26	2.30	1400	ND	28	90
B2-16	05/09/88	ND	56	1000	6.9	190	10	20	0.24	2.40	1500	ND	30	88
B2-16	06/20/88	ND	53	890	5.3	180	10	16	0.21	2.10	1400	ND	29	84
B2-16	07/25/88	ND	52	730	0.1	160	8	21	0.05	1.90	1600	ND	24	76
B2-16	09/19/88	ND	74	1200	0.21	180	5	8 ?	0.05	1.00	1400	ND	72 ?	81
B2-16	11/14/88	ND	45	570	6.0	110	5	16	0.07	1.80	1000	ND	29	54
B2-16	01/09/89	2	39	480	7.5	89	5	17	0.12	2.10	960	3600	25	48
B2-16	03/06/89	ND	35	500	3.4	100	5	18	0.11	2.40	1000	ND	30	50
B2-16	04/11/89	10 ?	40	650	3.3	130	7	18	0.23	2.10	1200	1900 ?	29	65
B2-16	06/06/89	2	39	700	3.0	140	9	15	0.18	1.90	1200	4700	27	74
B2-16	08/21/89	2	44	720	3.7	170	11	16	0.36	2.30	1300	5000	31	97
B2-16	10/29/89	ND	49	620	3.8	200	11	15	0.29	3.10	1500	ND	30	95
B2-16	03/12/90	ND	38	690	2.5	140	8	17	0.19	2.10	1200	ND	27	77
B2-16	04/30/90	ND	36	710	8.5	140	8	16	0.19	2.00	1300	ND	26	79
P4	02/08/88	ND	7	7600	49.0	780	110	28	ND	0.89	4800	ND	ND	660

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P4	03/14/88	ND	3	6600	52.0	690	100	28	1.10	1.40	6000	ND	16	600
P4	04/04/88	ND	6	5200	72.0	770	120	43	1.30	1.60	4000	ND	18	430
P4	04/18/88	ND	9	6400	61.0	890	140	33	1.60	1.60	6200	ND	20	560
P4	05/09/88	ND	8	13000	93.0	2000	220	50	2.60	3.20	10000	ND	29	1300
P4	05/30/88	ND	7	11000	77.0	1800	200	50	2.20	2.10	8800	ND	28	1000
P4	07/25/88	ND	13	9600	72.0	1700	220	51	2.20	1.60	11000	67000 ?	28	1000
P4	08/22/88	ND	12	9500	62.0	1700	200	46	1.90	1.40	10000	ND	25	960
P4	10/17/88	ND	22	9800	33.0	1500	64	14	1.20	4.00	11000	ND	46	780
P4	11/14/88	ND	7	11000	100.0	1900	210	60	2.10	3.40	9000	ND	34	1000
P4	01/09/89	2	5	8800	160.0	1700	190	71	2.00	4.20	8900	28000	30	950
P4	03/06/89	63	5	8200	63.0	1500	180	40	1.40	1.60	7100	27000	30	780
P4	05/22/89	ND	5	9800	74.0	1600	190	49	2.10	1.80	7400	ND	39	950
P4	08/21/89	ND	7	9000	120.0	1900	200	33	1.80	2.70	8400	ND	45	900
P4	10/29/89	ND	17	8100	68.0	1500	180	72	1.50	19.00 ?	7300	ND	12	780
P4	03/12/90	ND	17	7200	56.0	1400	160	54	2.50	5.00	6500	ND	31	720
P4	04/30/90	ND	17	8300	76.0	1600	180	40	2.10	1.50	7600	ND	49	830
P5	02/08/88	ND	150	5800	21.0	560	37	10	ND	1.60	4600	ND	ND	500
P5	03/14/88	ND	220	3700	21.0	620	33	10	0.67	2.10	4500	ND	21	380
P5	04/04/88	ND	270	4700	29.0	660	4	15	0.72	2.00	4300	ND	21	300
P5	04/18/88	ND	280	5100	28.0	690	37	13	0.84	2.10	5000	ND	23	350
P5	05/09/88	ND	400	10000	36.0	1400	62	16	1.30	3.40	11000	ND	36	770
P5	05/30/88	ND	360	11000	38.0	1400	63	16	1.30	6.60	11000	ND	36	770
P5	07/25/88	ND	330	8600	32.0	1100	46	16	1.10	2.70	11000	74000 ?	34	560
P5	08/22/88	ND	320	7900	19.0	1000	42	15	0.99	2.50	9700	ND	31	510
P5	10/17/88	ND	7	12000	100.0	2000	200	55	2.20	2.60	10000	ND	32	1100
P5	11/14/88	ND	410	9300	96.0	1300	51	18	1.80	4.60	9700	ND	46	620
P5	01/09/89	2	360	7400	64.0	1000	39	23	0.72	3.50	8400	30000	40	430
P5	03/06/89	71	280	7200	8.7	990	50	6	0.64	4.50	7100	29000	39	390
P5	05/22/89	ND	350	8500	9.6	1200	63	17	1.10	2.40	8400	ND	50	560
P5	08/21/89	ND	430	11000	4.7	2200	200	0	1.40	4.60	8100	ND	52	890
P5	10/29/89	ND	240	6600	0.1	1000	57	38	0.71	2.70	7300	ND	11	440
P5	03/12/90	ND	240	7900	20.0	1100	64	31	1.80	4.60	8500	ND	40	480
P5	04/30/90	ND	260	6600	6.2	930	31	4	1.30	1.40	7900	ND	55	250
P6	02/08/88	ND	14	12000	47.0	1200	130	11	ND	1.40	6300	ND		1100
P6	03/14/88	ND	8	5700	43.0	950	120	8	1.90	3.40	7100	ND	9	1100
P6	04/04/88	ND	11	7200	55.0	950	140	14	2.10	2.40	5500	ND	9	730
P6	04/18/88	ND	15	8000	54.0	1100	140	11	2.40	2.20	6800	ND	9	780
P6	05/09/88	ND	21	26000	83.0	5200	320	16	5.30	6.80	26000	ND	17	4500
P6	05/30/88	ND	21	26000	82.0	5100	310	17	5.20	6.10	26000	ND	17	4300
P6	06/20/88	ND	21	26000	80.0	5100	310	18	5.10	7.10	25000	ND	18	4300
P6	07/25/88	ND	35	9800	67.0	3900	320	17	5.10	3.40	28000	190000 ?	17	2700
P6	08/22/88	ND	34	9800	69.0	3900	310	16	4.70	2.90	27000	ND	17	2700
P6	10/17/88	ND	19	30000	91.0	5100	270	14	4.80	6.70	27000	ND	21	4200
P6	11/14/88	ND	19	30000	88.0	5000	280	18	5.40	7.10	25000	ND	22	4100
P6	01/09/89	2	15	31000	410.0 ?	4900	280	120	5.00	9.40	27000	87000	25	4200

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P6	03/06/89	170	16	24000	36.0	3900	230	0	3.10	5.90	19000	76000	20	3100
P6	05/22/89	ND	17	31000	91.0	4900	290	18	6.00	2.30	24000	ND	22	4300
P6	08/21/89	ND	22	29000	110.0	5400	290	0	3.70	7.30	25000	ND	26	4100
P6	10/29/89	ND	60	29000	78.0	4700	270	94	4.30	4.00	25000	ND	0	3800
P6	03/12/90	ND	61	27000	63.0	4700	250	31	4.10	12.00	23000	ND	30	3500
P6	04/30/90	ND	67	34000	71.0	5300	300	0	6.50	0.1	29000	ND	63 ?	4400
		Wells at the base of or below the tailings												
P1	02/08/88	ND	0.49	680	16.0	293	11.0	18	ND	0.012	920	ND	ND	3
P1	03/14/88	ND	1.20	1100	13.0	550	21.0	17	0.170	0.270	2200	ND	25	59
P1	04/04/88	ND	0.38	260	19.0	410	19.0	24	0.190	0.090	1200	ND	15	13
P1	04/18/88	ND	0.42	170	10.8	270	10.3	13	0.120	0.070	1100	ND	9	8
P1	05/09/88	ND	0.61	520	17.3	512	20.6	19	0.244	0.000	1694	3572	17	37
P1	05/30/88	ND	0.40	543	17.5	765	35.0	18	0.375	0.040	1769	ND	24	26
P1	06/20/88	ND	0.30	495	23.2	443	23.6	27	0.156	0.020	816	ND	18	9
P1	04/10/89	ND	0.04	59	18.1	397	11.9	24	0.000	0.060	922	ND	12	6
P1	05/22/89	ND	0.85	315	12.3	654	33.4	14	0.310	0.380	2055	ND	25	35
P1	06/06/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P1	06/27/89	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
P1	04/30/90	ND	0.28	79	20.0	414	12.3	25	0.120	0.040	881	ND	15	14
P1	06/10/90	ND	0.29	129	23.6	366	19.6	29	0.170	0.050	1059	ND	14	17
P2	02/08/88	ND	0.01	150	6.2	99	8.3	19	ND	0.05	310	ND	ND	0.01
P2	03/14/88	ND	0.18	160	6.0	200	12.0	16	0.05	0.05	490	ND	25	0.13
P2	04/04/88	ND	0.11	110	7.7	120	8.6	25	0.05	0.05	310	ND	18	0.15
P2	04/18/88	ND	0.02	79	6.2	98	6.5	22	0.05	0.05	180	ND	14	0.01
P2	05/09/88	ND	0.03	120	7.5	120	7.5	24	0.05	0.05	320	ND	18	0.14
P2	05/30/88	ND	0.03	110	7.3	130	8.1	22	0.05	0.05	320	ND	20	0.08
P2	06/20/88	ND	0.10	110	6.8	140	9.6	22	0.05	0.56	410	ND	19	0.22
P2	07/25/88	ND	0.07	95	6.9	120	7.5	23	0.05	0.09	300	880	16	0.08
P2	08/22/88	ND	0.11	190	7.1	140	9.2	21	0.05	0.05	1200	ND	14	4.40
P2	10/17/88	ND	0.09	170	12.0	170	9.4	34	0.05	0.05	560	ND	17	6.90
P2	11/14/88	ND	0.20	270	12.0	200	11.0	31	0.08	0.06	630	ND	15	16.00
P2	01/09/89	ND	0.50	700	11.0	300	16.0	31	0.10	0.13	850	1400	22	84.00
P2	03/06/89	ND	0.15	220	9.1	170	11.0	29	0.05	0.21	510	ND	19	16.00
P2	04/11/89	ND	0.03	110	7.8	150	8.6	23	0.05	0.05	370	ND	16	0.39
P2	05/22/89	ND	0.13	100	7.5	150	9.2	27	0.05	0.08	340	ND	19	0.25
P2	08/21/89	ND	1.40	500	16.0	350	27.0	28	0.23	0.14	960	ND	23	49.00
P2	10/29/89	ND	0.59	240	9.5	190	11.0	25	0.08	0.14	640	ND	12	19.00
P2	03/12/90	ND	0.39	120	8.2	170	9.8	31	0.05	0.23	470	ND	9	6.40
P2	04/30/90	ND	0.23	87	7.5	130	7.7	24	0.02	0.05	340	ND	15	0.64
P3	02/08/88	ND	0.01	15	3.0	90	0.7	33	ND	0.05	350	ND	ND	0.01
P3	03/14/88	ND	0.15	15	1.8	180	1.0	28	0.05	0.11	500	ND	38	0.09
P3	04/04/88	ND	0.02	8	1.6	110	0.6	40	0.05	0.05	300	ND	23	0.09

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P3	04/18/88	ND	0.01	36	2.0	100	1.3	36	0.05	0.05	250	ND	23	3.40
P3	05/09/88	ND	0.07	6	2.0	110	0.6	40	0.05	0.05	310	ND	27	0.12
P3	05/30/88	ND	0.04	7	2.3	120	0.7	42	0.05	6.50	290	ND	28	0.14
P3	06/20/88	ND	0.01	8	2.4	150	0.7	48	0.05	0.13	320	ND	29	0.07
P3	07/25/88	ND	0.11	9	2.1	190	1.1	29	0.05	0.13	520	1600	31	0.36
P3	08/22/88	ND	0.07	6	2.1	110	0.6	33	0.05	0.05	930	ND	26	0.07
P3	10/17/88	ND	0.13	19	2.5	130	0.7	50	0.05	0.05	320	ND	27	1.10
P3	11/14/88	ND	0.10	140	2.9	150	1.9	48	0.05	0.08	430	ND	27	18.00
P3	01/09/89	2.0	0.02	4	2.4	130	0.6	43	0.05	0.05	290	920	26	0.03
P3	03/06/89	ND	0.06	5	1.9	110	1.0	43	0.05	0.18	280	ND	26	0.20
P3	04/11/89	ND	0.01	2	2.2	110	0.6	34	0.05	0.05	300	ND	22	0.08
P3	05/22/89	ND	0.06	4	1.3	130	0.6	39	0.05	0.05	280	ND	25	0.09
P3	08/21/89	ND	0.19	11	1.9	200	1.5	23	0.05	0.05	300	ND	29	0.19
P3	10/29/89	ND	0.14	20	1.0	110	1.1	37	0.05	0.06	290	ND	28	0.68
P3	03/12/90	9.4	0.18	6	1.5	110	0.7	41	0.05	0.24	310	ND	21	0.61
P3	04/30/90	ND	0.08	5	1.9	110	0.6	36	ND	0.07	300	ND	26	0.16
P3A	06/18/90	ND	0.32	146	16.3	165	14.4	33	0.02	0.05	612	ND	17	7.55
P3A	03/11/91	ND	0.33	172	26.0	386	23.2	48	0.04	0.43	888	1890	19	2.79
P3A	06/03/91	ND	0.27	164	21.3	296	17.0	36	0.02	0.04	692	1965	15	2.02
P3A	03/30/92	0.0	0.02	234	22.4	377	22.7	35	0.03	0.00	868	2500	15	1.37
P3A	05/26/92	0.0	0.03	240	23.3	383	21.6	35	0.00	0.08	882	2425	16	1.55
P3A	08/26/92	ND	0.03	441	27.5	560	32.2	40	0.03	0.06	1416	4265	14	1.44
P3A	11/17/92	ND	0.40	426	28.0	591	32.4	38	0.00	0.00	1289	3716	17	1.60
P3A	03/01/93	ND	0.51	476	26.3	521	28.1	34	0.00	0.02	1282	3822	16	1.23
P3B	06/18/90	ND	0.92	512	46.0	260	0.0	66	0.03	0.08	1142	ND	24	2.56
P3B	03/11/91	34.9	1.10	943	50.0	610	72.2	65	0.06	0.88	1732	5302	20	5.26
P3B	06/03/91	ND	1.36	982	52.1	577	74.2	66	0.09	0.05	1699	5021	20	4.52
P3B	03/30/92	ND	0.04	942	55.9	617	73.5	63	0.08	0.06	1851	5423	19	3.34
P3B	05/26/92	0.0	0.02	1059	58.6	779	103.1	66	0.12	0.14	2333	6682	20	5.84
P3B	08/26/92	ND	0.02	1371	62.9	819	120.8	64	0.13	0.04	2566	8513	21	5.38
P3B	11/17/92	ND	0.40	1574	62.0	1127	125.0	66	0.10	0.10	2749	8291	22	15.80
P3B	03/01/93	ND	0.27	1565	65.4	933	115.9	63	0.18	0.16	2773	8044	22	6.47
P3C	06/18/90	ND	0.07	9	9.3	74	0.3	31	0.00	0.05	227	ND	24	0.17
P3C	03/11/91	ND	0.16	108	6.2	102	3.2	15	0.00	0.26	345	2102	9	0.15
P3C	06/03/91	ND	0.23	161	11.3	140	4.1	26	0.03	0.13	453	1343	19	0.11
P3C	03/30/92	ND	0.05	241	13.5	157	7.8	25	0.03	0.00	538	1574	17	1.77
P3C	05/26/92	ND	0.02	201	15.7	145	7.5	27	0.03	0.07	510	1419	18	3.40
P3C	08/26/92	0.0	0.03	463	18.1	251	15.8	28	0.04	0.08	954	2893	19	ND
P3C	11/17/92	ND	0.30	413	18.0	261	14.0	29	0.00	0.30	919	2740	20	13.20
P3C	03/01/93	ND	0.45	472	15.9	204	14.5	23	0.09	0.00	838	2392	19	14.38

APPENDIX C.—SUMMARY OF SEM ANALYSIS OF SAMPLES TAKEN AT BASE OF AND BELOW TAILINGS

1988 SAMPLES

Photomicrographs from SEM examination of polished sections of the 1988 and 1990 samples were taken. The actual photographs are not included in this RI but are available by contacting any of the authors. In this appendix, the SEM observations are described for each sample, including observations that were not recorded by photomicrograph.

Sample P-4-A (From well P4, 0 to 7.6 cm below tailings.)

Barium sulfate (the mineral barite) is a fairly common constituent of the fine-grained fraction of sample P-4-A. Numerous barite grains, 2 to 8 μm in size, in a matrix rich in iron, aluminum, and silicon (perhaps an amorphous precipitate?) were observed. Elsewhere on this sample, rectangular gypsum crystals were found, as was a grain of iron-titanium oxide in a matrix of silica.

Sample P-4-B (From well P4, 7.6 to 22.9 cm below tailings.)

Framboidal spheroids composed of iron and sulfur were observed in sample P-4-B. Although the mineralogy of these spheroids has not been determined, they are assumed to be pyrite based on results of numerous other studies (e.g., Berner, 1970). The framboids range in diameter from about 6 to 20 μm. Regardless of the total size of the framboidal spheroid, the individual spheres within the spheroid seem to be about 0.8 μm in size.

Sample P-4-C (From well P4, 22.9 to 25.4 cm below tailings.)

In addition to pyrite framboids about 8 μm in diameter, this sample contained a mottled mass of iron oxide. Also, various shell fragments (snails?) showed only calcium during EDS and are probably composed of calcium carbonate. A grain with titanium and silica and in a silica matrix probably represents sphene trapped in quartz.

Sample P-5-A (From well P5, 0 to 2.5 cm below tailings.)

This sample contained a relatively large (100 to 200 μm) grain cluster of gypsum (calcium and sulfur on EDS). Barite grains in an iron-aluminum-silicon matrix were also observed.

Sample P-5-B (From well P5, 2.5 to 12.7 cm below tailings.)

Barite was observed in sample P-5-B, as well as a limited amount of framboidal pyrite particles about 8 μm in diameter.

Sample P-5-C (From well P5, depth unknown.)

A grain of galena was found in quartz. Antimony and silver were detected by EDS on this grain, indicating the presence of a sulfosalt mineral. No pyrite framboids were found. Some gypsum, with a lead-rich core, was observed.

Sample P-6-A (From well P6, 0 to 10.1 cm below tailings.)

Pyrite framboids of about 8 μm in diameter were found in this sample. One of the framboids has an oxidation rind in which the relative amount of sulfur is less than in the central portion. Because the rind is thinner, about 2 μm, than the spatial resolution of the SEM for semiquantitative analysis, it seems probable that the rind is composed entirely of iron (iron oxide, or goethite). Also found in this sample were grains of barite and an iron-titanium oxide (ilmenite?).

Sample P-6-B (From well P6, 10.1 to 22.9 cm below tailings.)

This sample contains a cluster of three pyrite framboids, each about 16 to 18 μm in diameter, plus a number of dispersed, individual spherules, which may simply represent a larger framboid damaged during sample preparation.

1990 SAMPLES

Sample B2A-1 (From well B2A, base of tailings.)

This sample appears to represent the bottom of the tailings, just above the organic layer. Barite was quite abundant. Also detected were K-feldspar, quartz, and iron oxide (goethite?). No sulfide grains, algae, or diatoms were seen in this interval.

Sample B2A-2 (From well B2A, 2.5 to 7.6 cm below tailings.)

Pyrite framboids from 2 to 6 μm in diameter were seen in this interval at the top of the organic layer. Radiolarian debris was abundant.

Sample B2A-3 (From well B2A, 30.5 to 40.6 cm below tailings.)

Volcanic ash was abundant in this interval. Excessive charging of the sample during SEM examination precluded taking any informative photographs.

Sample P3A-1 (From well P3A, 2.5 to 7.6 cm below tailings.)

Some pyrite framboids about 6 μm in diameter were observed along with abundant radiolarian debris and algal cysts (crysophytes).

Sample P3A-2 (From well P3A, 30.5 to 40.6 cm below tailings.)

Only a few pyrite framboids (about 4 μm in diameter) were found along with abundant algal cysts and radiolarian debris.

Sample P3A-3 (From well P3A, 48.3 to 58.4 cm below tailings.)

No pyrite framboids were found in this sample, which apparently consists largely of devitrified volcanic glass. An EDS spectrum of the material showed silicon, aluminum, potassium, and calcium, some of the major elements in dacitic-to-rhyolitic glass from volcanic ashfalls typical of the region.

Sample P3C-1 (From well P3C, base of tailings.)

This sample presumably contained oxidized tailings from above the organic layer. Fine-grained barite was very abundant, along with iron oxides. No sulfide minerals were found. No SEM photomicrographs were taken because of excessive charge buildup on the sample.

Sample P3C-2 (From well P3C, 0 to 7.6 cm below tailings.)

At the top of the organic-rich layer, abundant pyrite framboids, 10 to 20 μm in diameter, were observed. Some algal cysts were also found.

Sample P3C-3 (From well P3C, 7.6 to 15.2 cm below tailings.)

This sample had abundant algal cysts (chrysomonads, which are the resting state of algae), possible volcanic glass shards, well-formed pyrite framboids, and abundant diatom and radiolarian fossils.

Sample P3C-4 (From well P3C, 60.9 to 76.2 cm below tailings.)

A tan-to-brown clay-rich layer looked to be composed of partially devitrified volcanic glass. An EDS spectrum showed abundant silica, with detectable aluminum, potassium, calcium, and iron, as would be expected from rhyolitic to rhyodacitic ashfalls.

Sample P3C-5 (From well P3C, 76.2 to 94 cm below tailings.)

Volcanic glass shards and algal cysts were observed by SEM, in this brown-to-tan layer, but no pyrite framboids. Macroscopically, some green material was present, perhaps a live colony of moss or algae.

APPENDIX D.—RESULTS OF CHEMICAL ANALYSES OF SOLID SAMPLES COLLECTED AT BASE AND BELOW TAILINGS

(Analyses conducted by IGAl, Inc., Cheney, WA)

IGAL, Inc.
111 College Ave.
Cheney, WA 99004
July 17, 1991

Si (ppm)

Sample No.	I	II	III	IV	V
P2A18	57	61	392	323	560
B2A20	5	103	405	278	365
P2A20	15	150	495	580	1210
P2A22	78	395	680	435	805
P3A19	125	520	428	1520	835
P3A22	62	265	860	605	1030
P3C24	15	75	218	125	362

Al (ppm)

Sample No.	I	II	III	IV	V
P2A18	35	232	733	365	2450
B2A20	15	270	1065	220	1075
P2A20	3	45	260	535	1760
P2A22	<1	95	518	420	2350
P3A19	<1	36	180	1570	575
P3A22	<1	105	522	920	6320
P3C24	<1	12	50	5	80

Fe (ppm)

Sample No.	I	II	III	IV	V
P2A18	50	428	1910	282	8450
B2A20	15	370	1368	150	6420
P2A20	7	5570	9710	4905	6750
P2A22	3	2750	2015	860	4675
P3A19	5	35	210	3300	1960
P3A22	8	1080	1075	1510	4225
P3C24	3	4750	1335	135	450

Mn (ppm)

Sample No.	I	II	III	IV	V
P2A18	12	1	8	<1	30
B2A20	15	6	18	1	8
P2A20	120	210	105	25	32
P2A22	72	80	<1	45	16
P3A19	60	122	30	60	3
P3A22	5	42	8	2	<1
P3C24	5	225	35	<1	<1

Mg (ppm)

Sample No.	I	II	III	IV	V
P2A18	201	16	62	35	1890
B2A20	162	20	33	21	542
P2A20	1980	632	225	120	1250
P2A22	1285	250	95	58	1025
P3A19	860	1750	232	73	175
P3A22	1015	1460	260	105	520
P3C24	180	3350	220	35	65

Ca (ppm)

Sample No.	I	II	III	IV	V
P2A18	506	37	530	83	145
B2A20	490	110	492	70	67
P2A20	14500	29450	5525	1610	1040
P2A22	12250	8320	1915	5018	1850
P3A19	16780	150850	27420	805	2885
P3A22	19660	119950	16935	3522	2615
P3C24	8840	324300	53230	42	1730

Cu (ppm)

Sample No.	I	II	III	IV	V
P2A18	10	52	12	18	405
B2A20	1	40	5	7	170
P2A20	1	4	1	3	48
P2A22	<1	3	1	6	45
P3A19	<1	4	1	4	34
P3A22	<1	4	1	6	46
P3C24	<1	3	1	2	8

Pb (ppm)

Sample No.	I	II	III	IV	V
P2A18	1	18	45	4	35
B2A20	<1	20	38	3	27
P2A20	<1	<1	<1	<1	5
P2A22	<1	<1	<1	<1	4
P3A19	<1	<1	<1	<1	2
P3A22	<1	<1	<1	<1	<1
P3C24	<1	<1	<1	<1	<1

I Exhchangable
II Bond to carbonates
III Bond to iron and manganese oxides
IV Bond to organic matter
V Bond to sulfides

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